CHESAPEAKE AND OHIO CANAL NATIONAL HISTORICAL PARK,

DISTRICT OF COLUMBIA / MARYLAND

WATER RESOURCES SCOPING REPORT

Don P. Weeks

Technical Report NPS/NRWRD/NRTR-2001/291

WATER RESOURCES DIVISION

National Park Service - Department of the Interior
Fort Collins - Denver - Washington

United States Department of the Interior • National Park Service

The National Park Service Water Resources Division is responsible for providing water resources management policy and guidelines, planning, technical assistance, training, and operational support to units of the National Park System. Program areas include water rights, water resources planning, regulatory guidance and review, hydrology, water quality, watershed management, watershed studies, and aquatic ecology.

Technical Reports

The National Park Service disseminates the results of biological, physical, and social research through the Natural Resources Technical Report Series. Natural resources inventories and monitoring activities, scientific literature reviews, bibliographies, and proceedings of technical workshops and conferences are also disseminated through this series.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

Copies of this report are available from the following:

National Park Service (970) 225-3500
Water Resources Division
1201 Oak Ridge Drive, Suite 250
Fort Collins, CO 80525

National Park Service (303) 969-2130
Technical Information Center
Denver Service Center
P.O. Box 25287
Denver, CO 80225-0287

CHESAPEAKE AND OHIO CANAL NATIONAL HISTORICAL PARK

DISTRICT OF COLUMBIA / MARYLAND

WATER RESOURCES SCOPING REPORT

Don P. Weeks[1]

Technical Report NPS/NRWRD/NRTR-2001/291

August, 2001

[1]Hydrologist, U.S. Department of the Interior, National Park Service, Water Resources Division, Denver, Colorado

United States Department of the Interior
National Park Service

CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

EXECUTIVE SUMMARY

Chesapeake and Ohio Canal National Historical Park (CHOH) was established in 1971 (P.L. 91-664) to preserve and interpret the historic and scenic features of the Chesapeake and Ohio Canal (C & O Canal) and to enhance recreational values of the canal. The 184-mile canal is an important relic of American history that originated through the influences of George Washington in the late 1700's to expand commercial transportation. Today the canal provides us an example of the early determination and ingenuity that ultimately led to one of the most successful countries in the world. Even by today's standards, C & O Canal represents an incredible engineering product that includes 11 aqueducts, 74 lift locks, and a 3,000-foot bricklined tunnel.

The canal is dependent on water from the Potomac River to maintain water levels within the canal prism. Unfortunately, the canal and Potomac are in continuous competition against each other. After the canal was completed in 1850, floods from the Potomac immediately began damaging the structures, a result of building within the river's 50-year floodplain. Thus there is an on-going struggle between NPS management and the natural environment.

Along with flooding, the National Park Service (NPS) is aware of both widespread and local threats, which have the potential to degrade CHOH's water resources. This, along with the lack of basic baseline water resource information, led the park to request assistance from the NPS Water Resources Division (WRD) to prepare this Water Resources Scoping Report (WRSR).

This report identifies and briefly describes the natural resources at CHOH and the significant water-related issues that park management is challenged to address. The report also summarizes the park's existing natural resources program to evaluate current staffing and natural resource management projects and to identify some of the park's management needs.

In certain cases, WRSRs meet the current water management needs for NPS units, where the number and complexity of issues are minimal. In such cases, park Resource Management Plan (RMP) project statements are included in the report to provide NPS management with the necessary action plan(s) to address the high-priority issues.

For CHOH, several water-related issues exist. Many of the issues presented in this report center around the lack of basic information (i.e., baseline data) that would better assist the NPS's understanding of CHOH's water resources. Thus, the NPS may be unaware of significant and/or time-sensitive issues because the natural resource information is not available.

The contents of this report are limited to information made available to the author during the time this report was prepared. Where appropriate, issue-specific recommendation(s) previously proposed by NPS management via CHOH planning documents (i.e., RMP) are included. As a result, descriptions of the natural resources and water resource issues vary in detail, and inclusion of issue-related recommendations is inconsistent.

As part of the effort by the NPS WRD to produce this report for CHOH, WRD staff traveled to the park in 2000. The purposes of this travel were to: 1) introduce elements of the WRSR effort to CHOH and NPS-National Capital Region Support Office, 2) become familiar with the water resources and high priority water-related issues at the park, 3) obtain pertinent information from park and other agency files, and 4) establish contacts with federal and state personnel and others with expertise on water resources in the region. The high-priority issues identified at CHOH during this effort include:

- Baseline Inventory and Monitoring
- Flood Management
- Minerals Extraction
- Agricultural Use Management
- Recreational Management
- Wetlands Management
- Hazardous Waste Management and Spill Contingency Planning
- Water Rights
- Coordination

Each of these issues has aspects that affect the park's water resources, though some may not be under NPS control; therefore, it is important to recognize the fact that multi-agency communication and coordination are essential to successfully manage CHOH's watershed. Based on the assessment of these issues, a recommendation and justification to produce a more comprehensive Water Resources Management Plan (WRMP) for CHOH is presented at the end of this report. The WRMP process encourages other stakeholders to participate with the NPS during and after plan development. This process, if carried through, will produce regional ownership of the WRMP, which is needed to effectively drive the plan's recommended actions.

INTRODUCTION

Chesapeake and Ohio Canal National Historical Park (CHOH) is centered around a 184.5-mile long canal and towpath that includes an infrastructure of 74 lift locks, 11 aqueducts, over 180 culverts, more than 50 waste weirs, 6 dams, and one 3,118 foot-long tunnel. The canal was constructed from Georgetown, District of Columbia to Cumberland, Maryland between 1828 and 1850, as an outgrowth of the colonial movement to connect the tidewater of the Potomac River with the western waters of the Ohio, which are separated by the Allegheny Mountains (National Park Service, 1978). The canal is considered by many to be the finest relic of America's canal-building history.

The objective of this report is to provide NPS management with a brief overview of CHOH's aquatic environments, existing water-related information and issues that pertain to CHOH, while also identifying some of the "information needs" that will better assist NPS management in providing a greater level of water resource protection. At the end of the report, an evaluation of this information is presented to determine if a more comprehensive Water Resources Management Plan (WRMP) is warranted for this NPS unit.

The initial information-gathering effort for this report included a 3-day visit by the author and David Vana-Miller (NPS-Water Resources Division) to CHOH in May 2000. Information was derived from many sources, including interviews with park management and other Federal and State agencies and review of existing natural resources information with emphasis on water resources. The author was also fortunate to visit many of the sites in CHOH (i.e., Cumberland, Old Town, Big Pool, Williamsport, Shepherdstown, Great Falls, Angler's Inn, etc.), which provided a better appreciation of the diverse water resources and associated issues.

Location, Legislation, and Management

CHOH begins (mile 0) at Georgetown in the District of Columbia and travels through Maryland, Virginia and West Virginia, before ending at Cumberland, Maryland (mile 184.5) (Figure 1). The National Park Service (NPS) administers 19,236.60 acres (14,068.92 Federal; 5,167.68 non-Federal) within CHOH's boundary and 153.82 acres outside its boundary (National Park Service, 1996a).

In 1938, President Franklin D. Roosevelt purchased the entire C&O Canal from the financially troubled B&O Railroad using authority granted under the National Industrial Recovery Act of 1933. Under Proclamation 3391, President Dwight D. Eisenhower created the Chesapeake and Ohio Canal National Monument in 1961. This monument included all canal property between Seneca and Cumberland, Maryland, but contained no funding and did not authorize any expansion or development. In 1971, CHOH was authorized by Public Law 91-664, "*Chesapeake and Ohio Canal Development Act*". The specific purposes of the park, as defined by this law were to, "preserve and interpret the historic and scenic features of the Chesapeake and Ohio Canal, and to develop the potential of the canal for public recreation, including such restoration as may be needed." Section 7 of CHOH's enabling legislation directs the park to be administered in accordance with the 1916 Organic Act, which directs the NPS to "…conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations." Some of the additional legislation and executive orders that guide management of CHOH's aquatic resources include the following, with a more comprehensive list presented in CHOH's Resources Management Plan (National Park Service, 1996a).

> The 1972 *Federal Water Pollution Control Act*, more commonly known as the *Clean Water Act*, was designed to restore and maintain the integrity of the nation's waters. States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water quality standards. Section 404 of the act requires that a permit be issued for discharge of dredged or fill materials in waters of the United States, including wetlands. The U.S. Army Corps of Engineers administers the Section 404 permit program. Section 402 of the act requires that a National Pollutant Discharge Elimination System (NPDES) permit be obtained for the discharge of pollutants from any point source into the waters of the United States. In general, all discharges and storm water runoff from major industrial and transportation activities, municipalities, and certain construction activities must be permitted by the NPDES program. The U.S. Environmental Protection Agency usually delegates NPDES permitting authority to the state.
>
> Congress passed the *National Environmental Policy Act* (NEPA) in 1969, which requires that federal actions which may have significant environmental impacts shall: "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment."
>
> *Executive Order 11988* requires all Federal agencies to "reduce the risk of flood loss…minimize the impacts of floods on human safety, health and welfare, and…restore and preserve the natural and beneficial values weaved by floodplain" (Goldfarb, 1988). Federal agencies are therefore required to implement floodplain planning and consider all feasible alternatives, which minimize impacts prior to construction of facilities or structures. As stated in the Special Directive 93-4, "If a proposed action is found to be in the applicable regulatory floodplain and relocating the action to a non-floodplain site is considered not to be a viable alternative, then flood conditions and associated hazards must be quantified as a basis for management decision making, and appropriate prescribed actions must be taken." A formal Statement of Findings must be prepared if the NPS decides to locate an action in an applicable regulatory floodplain. This is an important mandate for the park since 85% of the

Figure 1. Chesapeake and Ohio Canal National Historical Park (map not complete).

tCHOH lands lie within the 50-year floodplain of the Potomac River (National Park Service, 1996a).

Executive Order 11990 directs the NPS to 1) provide leadership and to take action to minimize the destruction, loss, or degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; 3) to avoid direct or indirect support of new construction in wetlands unless there are no practicable alternative to such construction and the proposed action includes all practicable measures to minimize harm to wetlands (National Park Service, 1998a).

Director's Order #2: Park Planning provides the policies and guidance related to park planning. The Park Service has a mandate in its Organic Act and other legislation to preserve resources unimpaired for the enjoyment of future generations. NPS park planning will help define what types of resource conditions, visitor uses, and management actions will best achieve that mandate. The NPS is to maintain an up-to-date general management plan (GMP) for each unit of the national park system. The purpose of the plan is to ensure that each park has a clearly defined direction for natural and cultural resource preservation and visitor use. The CHOH GMP, called the "General Plan", was approved in 1976 and is due for revision. A park's Resources Management Plan (RMP) describes the specific management actions needed to protect and manage the park's natural and cultural resources. The RMP identifies existing resources and conditions, present actions, and identifies future needs consistent with legislative and administrative guidance, resource significance, and other park planning documents. CHOH's most recent RMP was approved in 1997 (National Park Service, 1996a). Discipline-specific planning documents that complement the RMP (e.g., Fire Management Plan, Water Resources Management Plan) are prepared for NPS units when warranted.

Demography and Land Use

CHOH is located in the Potomac River Basin, where the quantity and quality of water in aquifers and streams will continue to be stressed by population growth and associated pressures. The Potomac River provides water for people, crops, livestock, industry, and the C&O Canal. It supports an important commercial fishery and a variety of other fish and wildlife in its estuary. The basin is also a source of outdoor recreation for millions of Americans (National Park Service, 1995). The general distribution of major land uses in the basin (urban, agriculture and forest) is presented in Figure 2.

Early settlement of the Potomac River Basin was influenced by the mountains and valleys that funneled settlers in common routes through areas where travel was easier. In 1943, approximately half the population of the Potomac River Basin lived in the Washington metropolitan area. In 1970, population of the basin was 3.6 million with 2.9 million (81%) concentrated in the metropolitan area (Feltz and Herb, 1977). The population within the basin increased an estimated 44 percent from 1970 to 1990. It is estimated that the population will increase an estimated 19 percent to 6.2 million between the years 2000 and 2020 (Ator *et al*., 1998).

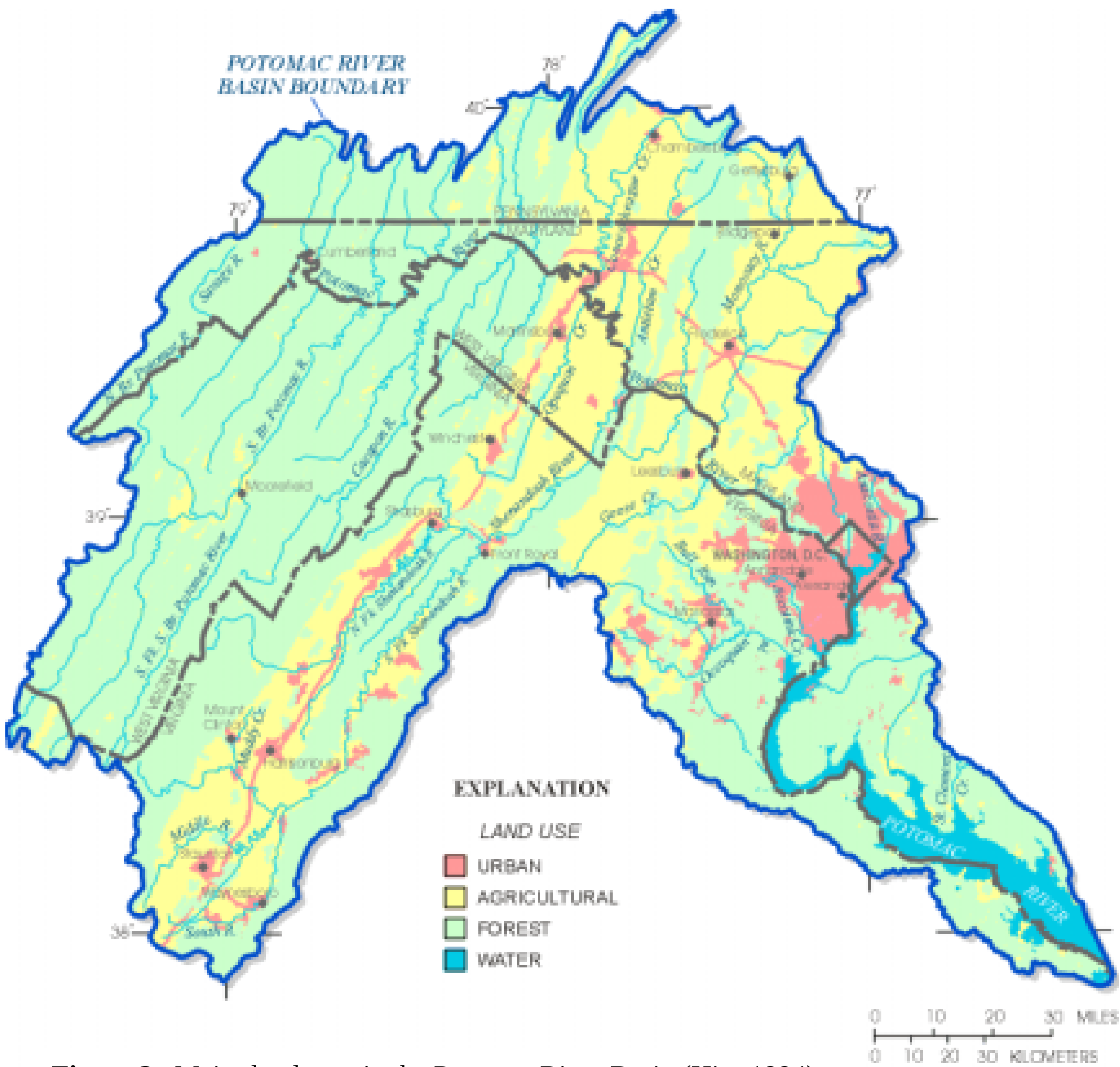


Figure 2. Major land uses in the Potomac River Basin (Hitt, 1994)

DESCRIPTION OF NATURAL RESOURCES

Climate

A temperate climate and moderate precipitation dominate the Potomac River Basin. The area is influenced by prevailing westerly winds, which are frequently interrupted by surges of cool northern and warm southern air masses. In the warmer half of the year, the basin is affected by showers and thunderstorms. These storms often cause flash flooding in the narrow valleys (Hobba, *et al*., 1972). Precipitation and air temperature can vary depending on the geographic location within the basin. Figure 3 presents climate data (1961-1990) from three locations along the C&O Canal; Washington D.C. (beginning), Hagerstown, MD (midpoint), and Cumberland, MD (end). Annual average precipitation ranges from 36 inches in Cumberland, MD to 38.6 inches in Washington D.C. As illustrated in Figure 3, precipitation is evenly distributed throughout the year, with a slight increase during the late spring and summer months. Average monthly air temperatures range from 20.3° F in January to 71.2° F in July, with warmer temperatures typically occurring in the District of Columbia where influences from a maritime climate are more prominent.

Physiography

As expected for a long linear NPS unit, the physiography, geology and hydrology varies at CHOH, which increases the complexity of natural resource management. The 184.5-mile long canal crosses four physiographic provinces. From east to west the provinces are the 1) *Coastal Plain*, 2) *Piedmont*, 3*) Blue Ridge*, and 4) *Valley and Ridge* (Ator *et al*., 1998) (see Figure 4). The topography of the *Coastal Plain* is a terraced landscape that stairsteps down from Great Falls (Fall Line) to major rivers and the coast. The *Piedmont* province is bounded on the east by the Fall Line, and on the west by mountains of the *Blue Ridge* province, approximately where Highway 15 crosses the Potomac River. The Piedmont is characterized by a gently rolling topography of deeply weathered bedrock, with some solid outcrop. The *Blue Ridge* province is a rugged region with steep slopes, narrow ridges and broad mountains with relatively high relief that basically includes park lands between Highway 15 and Highway 34 (Shepherdstown, WV). The *Valley and Ridge* province includes the *Great Valley* subprovince (Shepherdstown to Fort Fredrick State Park), which is characterized by broad valleys with low to moderate slopes underlain by carbonate rocks (cave region). The remainder of the *Valley and Ridge* province (Fort Fredrick to Cumberland, MD) consists of elongated parallel ridges and valleys (William & Mary, 2000).

Geology

The *Coastal Plain* is underlain by a thick wedge of sediments that increases in thickness from the Fall Line toward the coast (Figure 4). The sediments are comprised of clays, sands and gravels eroded from the Appalachian Mountains and carried eastward. These sediments rest on an eroded surface of Precambrian to Mesozoic rock. Rocks are strongly weathered in the *Piedmont's* humid climate and bedrock is generally buried under a thick (2 - 20 m) blanket of saprolite (typically soft clay-rich decomposed rock formed in place by chemical weathering of igneous, sedimentary or metamorphic rocks). Outcrops are commonly restricted to stream valleys where saprolite has been removed by erosion. A variety of igneous and metamorphic rocks make up the bedrock of the *Piedmont* province, ranging in age from Proterozoic to Paleozoic (William & Mary, 2000). The *Blue Ridge* exposes some of the oldest rocks in the region, with granitic gneiss over a billion years old (Southworth *et al*., 2000). This province is allochthonous

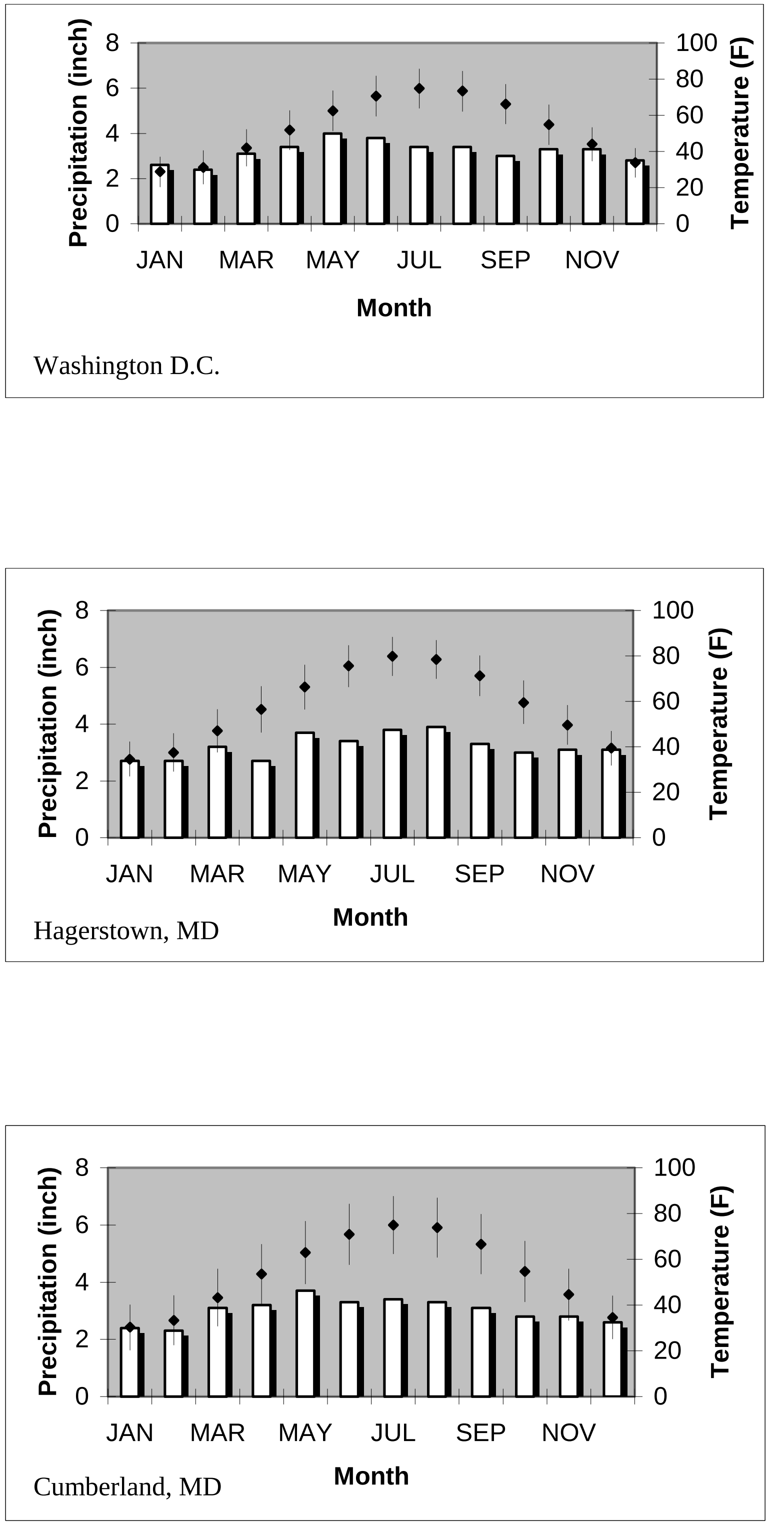


Figure 3. Monthly Mean Precipitation (bars) and Air Temperature Range (diamond-whiskers) (1961-1990), Washington D.C., Hagerstown, MD, and Cumberland, MD (National Climate Data Center, 2000).

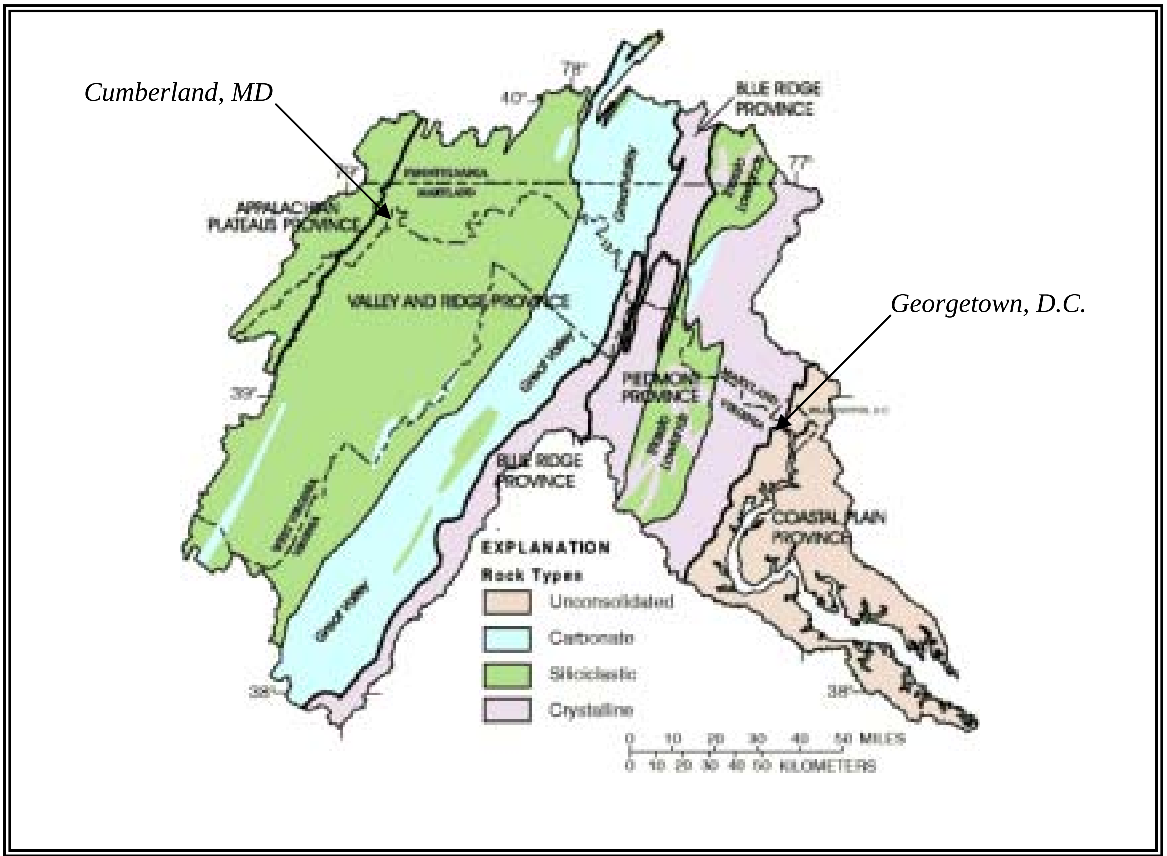


Figure 4. Generalized physiography and geology in the Potomac River Basin (modified after Ator, *et al*., 1998).

(formed elsewhere than its present location) and has been thrust to the northwest over Paleozoic rocks of the *Valley and Ridge* province. Although earlier deformation events are recorded in the older igneous and metamorphic rocks, the *Blue Ridge* is a contractional structure that has experienced deformation and crustal shortening during the Paleozoic. The *Valley and Ridge* consists of folded Paleozoic sedimentary rock. The *Great Valley* subprovince was the location of a shallow tropical ocean where carbonates were deposited for 70 million years. Karst topography is characteristic of the *Great Valley* and many caverns and sensitive aquatic habitats are located in this region (William & Mary, 2000). It should be noted that local and regional hydrological systems resulting from karst processes can be directly influenced by surface land use practices. The NPS is required to manage karst terrain to maintain the inherent integrity of its water quality, spring flow, drainage patterns, and caves (National Park Service, 2000a). Paleozoic sedimentary rock of the *Valley and Ridge* located outside of the Great Valley subprovince were folded and moved westward along thrust faults (William & Mary, 2000).

Soils

Soil development is a direct result of a wide variety of environmental factors such as parent materials, climate, physiography, plant, animal and human interactions, which occur over time. The Natural Resources Conservation Service (NRCS) and the NPS are currently under an Interagency Agreement to develop a soil survey for CHOH. Preliminary information provided by NRCS indicates that a wide variety of soil development is present, which is directly related to the variability of the climate, physiography and geology of the area (Biggam, pers. comm., 2001).

Soils in the upland portions of the *Piedmont* and *Blue Ridge* provinces in CHOH are generally well drained, moderately deep to deep soils forming in a variety of parent materials. Also present are soils that contain dense layers (fragipans) that are restrictive to roots, and are fairly impermeable to water movement. Soils in the *Coastal Plain* portion tend to be sandier than those in the *Piedmont* region, and express a wide variety of soil drainage classes from very poorly drained to excessively drained. Soils on floodplains tend to be deep, somewhat poorly to poorly drained, and are dominated by silt loams and silty clay loams textures (Biggam, pers. comm., 2001).

The *Great Valley* subprovince of the *Valley and Ridge* province contains limestone derived soils found in the *Great Valley* region that are highly productive for agriculture uses, and vast acreage's of forests have been cleared. The Nature Conservancy has estimated that only 1500 acres of an original 500,000 acres of limestone forest remains undisturbed in Maryland, with most of these undisturbed areas lying within the boundaries of CHOH (National Park Service, 1996a).

There are also a fair amount of anthropogenic soils (soils influenced by modern man's activities) located adjacent to the canal and historic structures that are highly variable in soil properties such as texture, permeability, and soil chemistry.

Hydrology

<u>Watersheds</u>

CHOH is located within the 14,670-mi^2 Potomac River drainage basin, the fourth largest watershed on the East Coast (Belval and Sprague, 1999; National Park Service, 1995). The Potomac River flows for 385 miles from the Allegheny Mountains to the Chesapeake Bay. Draining almost 15,000 square miles in four states, the Potomac is a major natural resource (National Park Service, 1995). The Potomac is one of nine river basins, and the second largest drainage that form the 64,000-mi^2 Chesapeake Bay watershed (see Figure 5). The Chesapeake Bay is the largest estuary in the United States, providing habitat for abundant and diverse wildlife populations and supporting an economy that includes fishing, shipping, and recreation. Currently 136 million people live in the Chesapeake Bay watershed, which is challenged with unprecedented development (Burke *et al*., 1999).

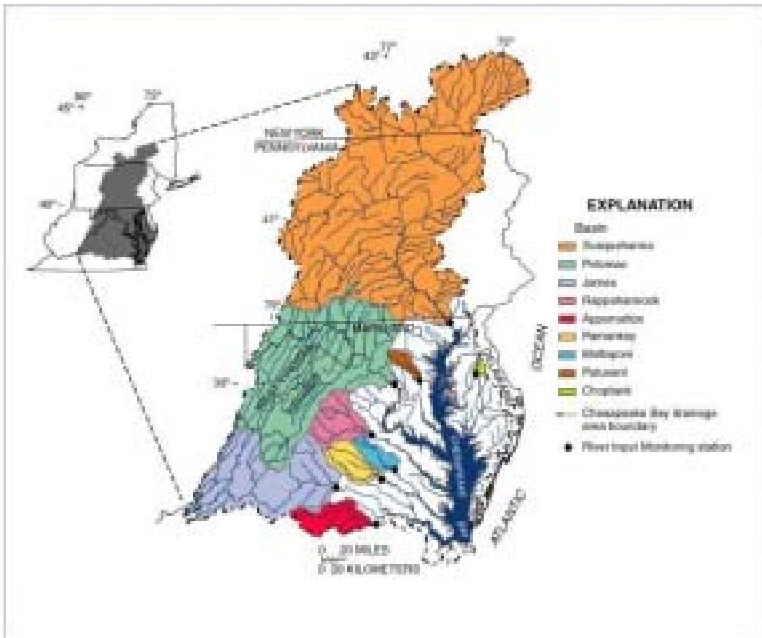
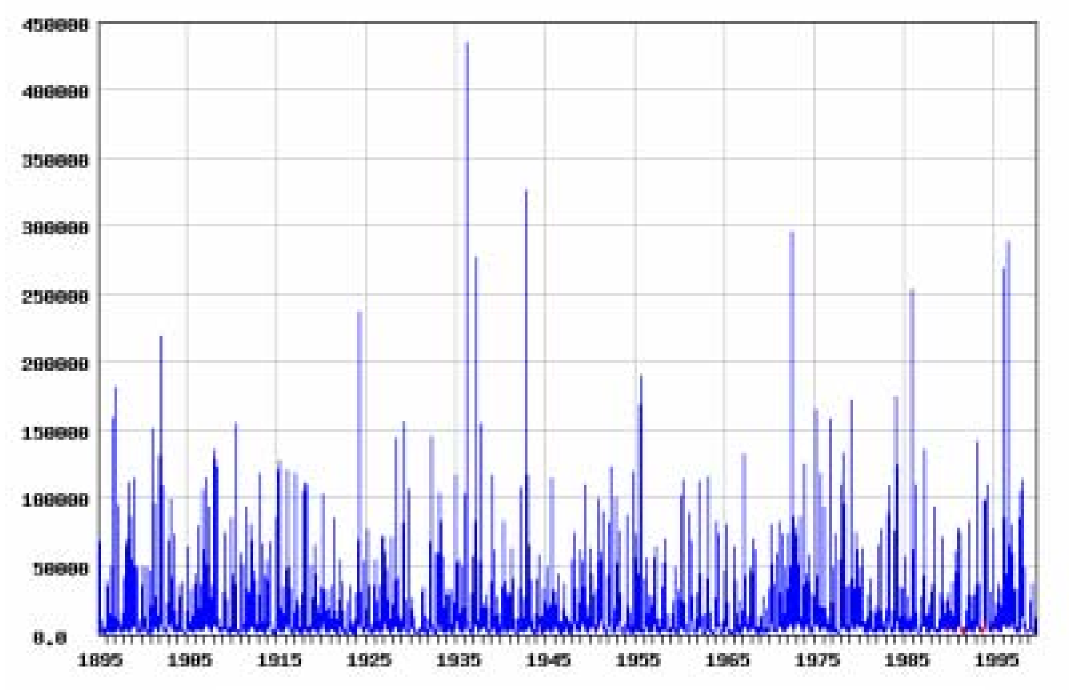


Figure 5. Location of major drainages in the Chesapeake Bay Basin (modified after Belval and Sprague, 1999)

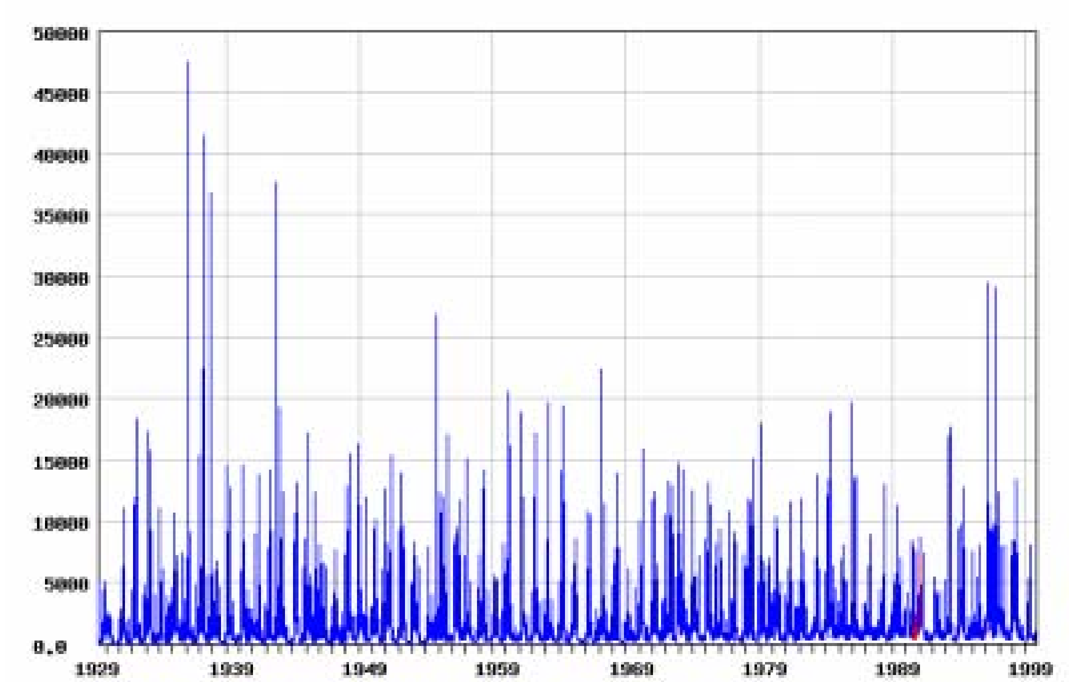
Surface Water

The North Branch and South Branch of the Potomac River flow northeast and unite about 15 miles southeast of Cumberland, Maryland. The Potomac River then flows east-southeast, with frequent meanders, forming the Maryland-West Virginia and Maryland-Virginia boundaries. Passing Harpers Ferry, West Virginia, it flows through a relatively steep-sided valley, interrupted by intermittent rapids and riffles. Ten miles north of Washington D.C, the river has cut a 200-foot gorge in which it descends some 90 feet in a 3-mile series of rapids known as the Great Falls of the Potomac. Below Great Falls, the river flows along gently sloping banks (U.S. Geological Survey, 1994). The Potomac River parallels C&O Canal along its entire 184.5-mile length. The river and its tributaries provide the canal's important water supply.

Because the Potomac River is largely unregulated by major impoundments, its flows tend to fluctuate widely depending on the climatic conditions in the Potomac River Basin. For example, the lowest and highest average daily flow recorded at Great Falls was 448 million gallons per day (mgd) (693 cubic feet per second (cfs)) in 1914 and 307,677 mgd (475,976 cfs) in 1936, respectively (National Park Service, 1978). The U.S. Geological Survey maintains several stream gages on the Potomac River. Historical daily discharge for the Potomac is presented in Figure 6 for two of these stream gage sites (Point of Rocks (1895-1999) and Cumberland, MD (1929-1999)) to illustrate the variability of



Potomac River (Point of Rocks), USGS Station 01638500



Potomac River (Cumberland, MD), USGS Station 0603000

Figure 6. Potomac River Daily Discharge (ft^3/sec) (U.S. Geological Survey, 2000).

discharge over the past several decades. Notice the high discharge recorded from the 1936 flood. Annual low flows typically occur during July, August, September, and October.

Low stream flows, including low flows in C & O Canal, can cause a variety of related problems. They detract from the total recreational value of a waterway, and are detrimental to aquatic life, since water quality usually deteriorates at low flows. Quantity of water for municipal and industrial uses may be reduced during low flows. Demand for water also tends to increase during dry periods (West Virginia Department of Natural Resources, 1981).

There are 161 perennial streams (37 named, 124 unnamed) that have been identified on the USGS 7.5-minute quadrangles, along with hundreds of intermittent streams that flow through the park. Many of the streams first flow into the canal and then exit to the Potomac River through waste weirs, while some of the larger water courses flow directly under the canal and into the river. U.S. Geological Survey streamflow-gaging stations with surface-water flowdata in the vicinity of CHOH are listed in Appendix A.

Natural stream channel stability is achieved by allowing the river to develop a stable dimension, pattern, and profile such that, over time, channel features are maintained and the stream neither aggrades nor degrades. For a stream to be stable it must be able to consistently transport its sediment load associated with local deposition and scour (Rosgen, 1996). Mathematical relations exist for a river’s unique morphological forms that provide meaning to an otherwise random appearing set of variables. Whenever proper attention to the “rules of the river” is not respected, adverse channel adjustments often result in damage to personal property (Rosgen, 1996).

Streamflow is influenced by natural basin and climatic characteristics as well as by anthropogenic activities. All rivers naturally experience high discharge at a time of heavy precipitation. A river channel can contain within its banks only a discharge of modest size. The greater discharges must overflow onto the valley floor. For this reason the flat valley floor or floodplain is indeed part of the channel during unusual storms (Leopold, 1997). Rosgen (1996) described floodplains as “channels” associated with infrequent, high magnitude, flood discharge. When humans use this part of the river for construction or agriculture, they are encroaching on the river (Leopold, 1997).

Riparian Forest

The natural riparian areas along C&O Canal contain diverse, dynamic, and complex biophysical habitats. These riparian areas are known to be important in controlling the physical and chemical environment of streams and in providing detritus and woody debris for streams and near-shore areas of water bodies. For example, riparian forests of mature trees (30 – 75 years old) are known to reduce delivery of nonpoint source pollution to streams and lakes (Lowrance *et al*., 1985). Riparian vegetation has well-known beneficial effects on bank stability, biological diversity and water temperatures of streams (Karr and Schlosser, 1978). These interfaces between terrestrial and freshwater ecosystems (i.e., littoral lake zones, marginal wetlands, riparian forests) are very sensitive to environmental change (Naiman and Décamps, 1997). Defining and ultimately managing riparian habitat is important to the preservation of CHOH's natural resources and the Chesapeake Bay watershed.

Implementation of Riparian Forest Buffer Systems (RFBS) within the Chesapeake Bay watershed as Best Management Practices (BMPs) has been encouraged for agricultural and urban areas (Lowrance *et al*., 1995). The NPS is one of 15 federal agencies participating in this regional effort to protect the Chesapeake Bay watershed. The NPS challenge within the parks of this watershed is to assure, to the extent feasible, that a forested or other riparian buffer protects all streams and shorelines. Like all the other participating agencies, the NPS will have until 2010 to identify and implement riparian forest buffer restoration projects (National Park Service, 1998b).

<u>Wetlands</u>

CHOH's wetlands represent transitional environments, located between uplands and deepwater areas. Flora within these wetland systems exhibits extreme spatial variability, triggered by very slight changes in elevation. Temporal variability is also great because the surface water depth is highly influenced by changes in precipitation, evaporation and/or infiltration. For the Cowardin classification system, a wetland must have one or more of the following attributes: (1) at least periodically, the land supports predominately hydrophytes; (2) the substrate is predominately undrained hydric soil; and (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin *et al*., 1979).

Approximately 85% of CHOH lands are within the 50-year floodplain of the Potomac River where favorable conditions for wetland environments exist. Most of the wetlands within CHOH are forested palustrine environments, but additional wetlands are found in riverine and lacustrine environments as well as virtually the entire canal bed. Thomson *et al*. (1999) identified 14 community type classifications for floodplain forest vegetation in the Potomac River watershed. Bear Island, owned by CHOH and the Nature Conservancy, has one of Maryland's best examples of floodplain forests (150 acres). At least 53 plant species considered rare, threatened, or endangered in Maryland are known to occur on Bear Island. Other high-quality wetland habitats documented at CHOH include the Dickerson Floodplain (90 acres), Cabin John Island (50 acres), and the Olmstead Island Complex, which includes Olmstead Island, Falls Island, and land adjacent to Lock #17 of C&O Canal (Thomson *et al*., 1999).

CHOH has National Wetland Inventory maps prepared by the U.S. Fish and Wildlife Service for 28 USGS quadrangles. These maps provide an inventory of wetlands in the park, as classified by the Cowardin system. However, much of the inventory has not been ground truthed and most of the smaller wetlands (<0.5 acre) were not included in the aerial survey.

Dams

Along the Potomac River, adjacent to C&O Canal, numerous dams were constructed, including several built to produced backwater for recharging the canal at various locations (Feeder Dams). The following is a list of these dams; (1) Feeder Dam 1 (approx. CHOH milepost 5.5), (2) Washington Aqueduct Dam (approx. CHOH milepost 14), (3) Feeder Dam 2 (approx. CHOH milepost 23), (4) Feeder Dam 3 (approx. CHOH milepost 62), (5) Feeder Dam 4 (approx. CHOH milepost 84), (6) Potomac Edison Dam (approx. CHOH milepost 100), (7) Feeder Dam 5 (approx. CHOH milepost 107), and (8) a larger replacement dam for Feeder Dam 8 (CHOH milepost 184.5), which was demolished in the 1950's. A recent breaching of Feeder Dam 1, at Little Falls, opened 10 miles of river habitat upstream to Great Falls. The breaching provided a new fish passage at the 12-foot-high dam designed to meet the needs of shad and other regional migratory fish. The Washington Aqueduct water supply dam is immediately above Great Falls. Beyond Great Falls to Feeder Dam 4, is 70 miles of river habitat that is partially blocked by Feeder Dam 2, and open at Feeder Dam 3, which is almost entirely demolished. Between Dams 4 and 5 is 20 miles of mostly impounded riverine habitat, blocked midway by a Potomac Edison low head (approx. 1 ft.) dam. Upstream of Dam 5 is five miles of impoundment and 95 miles of riverine habitat to the next blockage at the replacement dam for Feeder Dam 8 (U.S. Fish and Wildlife Service, 2000). This replacement dam at milepost 184.5 is critical to the success of the Cumberland C&O rewatering project.

Two hydroelectric facilities operated by Allegheny Energy Inc. are located at Feeder Dams 4 and 5. These dams, owned by the NPS, are leased to the utility. Allegheny Energy is currently developing applications for a new Federal Energy Regulatory Commission (FERC) license for these two hydroelectric facilities, since the previous agreement expired in 1998. The resource agencies participating in this license process are; CHOH, U.S. Fish and Wildlife Service, West Virginia Department of Natural Resources, and Maryland Department of Natural Resources. The NPS manages recreational and land resources on the Maryland side of these dams. The State of Maryland manages the aquatic resources and recreational uses on the river, the State of West Virginia manages recreation and land resources on the West Virginia side of the dams, and the U.S. Fish and Wildlife Service is involved due to the migratory American eel and other fish species passage over the dams. As part of the license process, several studies have been requested by the resource agencies for Allegheny Energy to address; recreation, land use, socioeconomics, and aesthetics. Currently, the group is working towards an agreement that will allow some version of the following: (1) for Allegheny Energy to annually pay for half the maintenance of Dams 4 and 5 (NPS pays remainder), (2) for Allegheny Energy to pay for a $34,000 Recreational Study and $7000 for NPS exhibits, (3) for Allegheny Energy to provide monetary compensation to the U.S. Fish and Wildlife Service for downstream fish entrainment, (4) for U.S. Fish and Wildlife Service to provide an official prescription for upstream eel passage (Allegheny Energy not responsible financially), and (5) provide nighttime shutdowns by Allegheny Energy during the three month eel migration period. Allegheny Energy submitted a draft FERC Application in July 2001. The final application is due December 2001 (Ingram, pers.

comm., 2001). CHOH is concentrating on recreational issues and the State of Maryland is concentrating on natural resource issues.

Ground Water

In 1962, per an NPS request, the U.S. Geological Survey began a ground water feasibility study to evaluate ground water as a potable water supply for CHOH facilities (Laughlin and Otton, 1964). The study included geological reconnaissance, well drilling, pumping tests, and ground water sampling to locate suitable ground water withdrawal sites. Ground water wells drilled and developed from this project resulted in supplying various recreational sites along the canal with potable water.

Evidence provided by base runoff and by transmissivity values, suggest that carbonate rock (i.e., dolomite, limestone) is the most favorable terrane in the Potomac River Basin for the development of large ground-water supplies. Although a few highly productive wells have been drilled in other types of rock, most of the larger capacity wells are in carbonate rock, commonly found in the *Great Valley* subprovince (Trainer and Watkins, 1975). In contrast, aquifers within the *Blue Ridge* and *Piedmont* province are characteristically small. The springs that occur in this region typically have low flow rates and many are seasonal (Otten and Hilleary, 1985). Analysis of well data in Maryland suggests joints are probably the most important structural feature for transmitting water within the *Blue Ridge* and *Piedmont* strata and these become less frequent with depth (Nutter 1974). Bedding planes can also contribute to aquifer transmissivity (Laughlin and Otton, 1964).

Ground water in the Potomac River Basin, in general, has good quality, but local problems do exist, including the presence of elevated iron, acidity, radon, pesticides, and nutrients (Baloch *et al*., 1973; Brakebill, 1993; Altor *et al*., 1998; Donnelly and Ferrari, 1998). The quality of ground water in karst (carbonate) landscapes (i.e., *Great Valley* subprovince) is particularly sensitive to landuse practices such as agriculture. Karst is a type of terrain in which the bedrock is made of soluble materials such as dolomite (calcium and magnesium carbonate) or limestone (calcium carbonate). Through time, precipitation and ground water drain through cracks and crevices in the carbonate bedrock, slowly dissolving the rock to form an underground network of conduits that often produce karstic features on the surface (i.e., sinkholes, caves, springs). As a result, surface contamination can easily infiltrate into the ground water via these open conduits. So it is not surprising that ground water samples collected within the *Great Valley* subprovince indicated a strong correlation between water quality and landuse (Brakebill, 1993). Karst aquifers are extremely susceptible to surface originating pollution sources or flow alteration as a result of above-ground anthropogenic activities (Poulson and Kane (1977), Stitt (1977)).

Ground water springs have been mapped by the Maryland Natural Heritage program in parts of Washington County. Some of these springs provide important habitat for rare invertebrates (National Park Service, 1996a). The Cave Resources Protection Act of

1988 has provided a major impetus to inventory and document karstic groundwaters on Federal lands.

Water Quality

The Interstate Commission on the Potomac River Basin (ICPRB) prepared a water quality trend assessment for the years 1962-1973. Based on this data, the ICPRB concluded that the Potomac from 10 miles below Cumberland to Great Falls (150 river miles) was generally of good quality and supported recreation and aquatic life. From Great Falls downstream 20 miles to the estuary, increasing nutrient levels, silt and bacteria were present (Maryland Department of Natural Resources, 1981). Since the 1970’s, monitoring of the Potomac River and tributaries has produced a better understanding of water quality.

The Clean Water Act (Section 303) and EPA Regulations (40 CFR, Section 130.7) require States to develop and publish a listing of all waters that do not fully support existing or designated beneficial uses, such as recreation or aquatic life support. According to Rosenlieb and Zander (2000), there are approximately 450 State listed 303d segments within CHOH, which translates to 125 miles of impaired streams.

The pollution of surface waters and ground waters by both point and non-point sources can impair the natural function of aquatic and terrestrial ecosystems, and diminish the utility of CHOH waters for visitor use and enjoyment. In the Potomac River Basin, the quality of streams and ground water is affected by a variety of natural and human processes. Several major types of chemicals found in water in the basin include nutrients, trace elements, pesticides, chlorinated industrial compounds and volatile organic compounds (Ator *et al*., 1998). Table 1 highlights the water quality assessment presented in a 1998 U.S. Geological Survey report. The report summarizes water quality data collected in the Potomac River Basin between 1992 and 1995, as part of the National Water-Quality Assessment (NAWQA) program for the Potomac River Basin Study Unit.

In 1996, the NPS Water Resources Division completed a comprehensive summary of existing surface-water quality data for CHOH, the *Baseline Water Quality Inventory and Analysis, Chesapeake and Ohio Canal National Historical Park*. The information contained in this report represents data retrievals from six EPA national databases; (1) Storage and Retrieval (STORET); (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); (5) Flow Gages (GAGES); and (6) Water Impoundments (DAMS). Most of the monitoring stations identified in this inventory represent either one-time or intensive single-year sampling efforts. One-hundred-sixty-one stations yielded longer-term records consisting of multiple observations for several important water quality parameters. The stations yielding the longest-term records within CHOH’s boundary are: (1) Potomac River At Point Of Rocks, MD (CHOH 0283); (2) Conococheague Creek at MD 68 Bridge, MD (CHOH 0376); (3) MD 68 Bridge, MD (CHOH 0375); (4) Just West of Intersection of Mooreshollow Road A, MD (CHOH 0506); (5) At Gaging Station 0.5 mile Below Bridge on U.S. Rt. 522, MD (CHOH 0426); and (6) Route 120 Bridge (under Chain Bridge),

Table 1. Water Quality Assessment of Potomac River Basin, 1992-1995 (Altor *et al.*, 1998).

Nutrient inputs to the Potomac River Basin are related to landuse. Agricultural areas receive the largest amounts of nutrients (45% nitrogen and 93% phosphorus inputs).
Elevated nitrogen concentrations in streams and ground water are common in areas of intensive row cropping and areas underlain by carbonate bedrock (i.e., limestone environments). Tributaries draining agricultural areas yield the greatest quantity of nitrogen to the Potomac River; streams draining agricultural and urban areas yield the greatest quantities of phosphorus.
In most waters of the Potomac River Basin, concentrations of nutrients do not pose a threat to human health or wildlife.
Commonly used pesticides are present in ground water in the Potomac River Basin, but typically at concentrations that are not threatening to human health. More pesticides were detected in streams than in ground water, but only rarely at concentrations threatening to aquatic life.
Pesticides are commonly detected in agricultural areas of the Potomac River Basin, particularly in areas of intense crop production (e.g., *Great Valley*). Maximum concentrations of most pesticides occur in streams during the spring and early summer months, coincident with their application to fields, although atrazine and metolachlor are present year round in streams in agricultural areas. Samples collected from forested areas rarely contained detectable pesticides.
Higher concentrations of agricultural chemicals were detected in streams located in carbonate terrain (i.e., limestone environments of the *Great Valley*).
Chlorinated organic compounds, mercury, and lead are present in streambed sediment at concentrations that have some potential to adversely affect aquatic life. Banned chemicals are still being detected in sediments (i.e., chlordane (banned in 1998), DDT (banned in 1972)).
Radon is present in ground water throughout the Potomac River Basin and is related to rock type. High levels of radon are typically associated with crystalline and siliciclastic rocks found in the eastern parts of the basin. Sixty-nine percent of ground water samples were greater than the EPA drinking-water standard (300 picocuries/liter).

Glebe Rd., VA (CHOH 0086). The results of the water quality screening criteria employed during the inventory identified 29 parameters that exceeded their criteria at least once within the study area. Dissolved oxygen, pH, chloride, chlorine, cyanide, antimony, cadmium, chromium, copper, lead, mercury, selenium, silver, zinc, and parathion exceeded their respective EPA criteria for protection of freshwater aquatic life. Chloride, fluoride, sulfate, nitrate, nitrite, nitrite + nitrate, antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, bis(2-ethylhexyl) phthalate, and carbon chloroform exceeded their respective EPA drinking water criteria. Bacteria concentrations (total coliform and fecal coliform) and turbidity exceeded screening limits established by the NPS-Water Resources Division for freshwater bathing and aquatic life, respectively. Alkalinity was below the threshold used by the NPS-Air Resources Division for determining potential sensitivity to acid deposition (buffering capacity). Specific information and selected graphical summaries on water quality data retrieved during this inventory can be found in the four-volume report, National Park Service (1996b).

The Potomac River Basin is known to have wide fluctuations in water and sediment discharge. Sedimentation is a problem for the watered sections of C&O Canal. When sediment rich waters from the Potomac River are diverted to recharge the canal, the suspended sediments quickly settle out of suspension due to the canal's lower gradient, and accumulate on the canal bed. Routine maintenance by the NPS to remove sediments from the canal bed can be very time consuming and costly. In 1996, such a project required an emergency removal of 200 freshwater mussels from the canal bed between towpath mile 3.0 and 4.0. The mussels were held over the winter and returned to the canal the following spring (Ingram, pers. comm., 2000). Highest sediment loads are generally associated with high runoff during late winter, early spring, and intense summer thunderstorms. For example, 76 percent of the sediment from the Anacostia Basin is carried during peak-flow conditions which occurred only 2.4 percent of the time (Secor, 1977). Cropland and construction sites are major sources of suspended sediment. Sediment contributions from individual sub-basins are not proportional to their drainage areas as illustrated in Figure 7. Land-use activity plays an important factor in sediment contributions. As sediments from land-use activities are introduced to the stream system and alternately deposited and transported, pollutants (i.e., nitrogen, phosphorus, metals, hydrocarbons) are adsorbed to the sediments, for better or worse, and translocated. These sorbed constituents can be brought into solution, depending upon ambient conditions and the solubility of the pollutants. Sediment transport and its impact is a dynamic process, always seeking equilibrium. An assessment of the impact is likewise dynamic (Feltz and Herb, 1977).

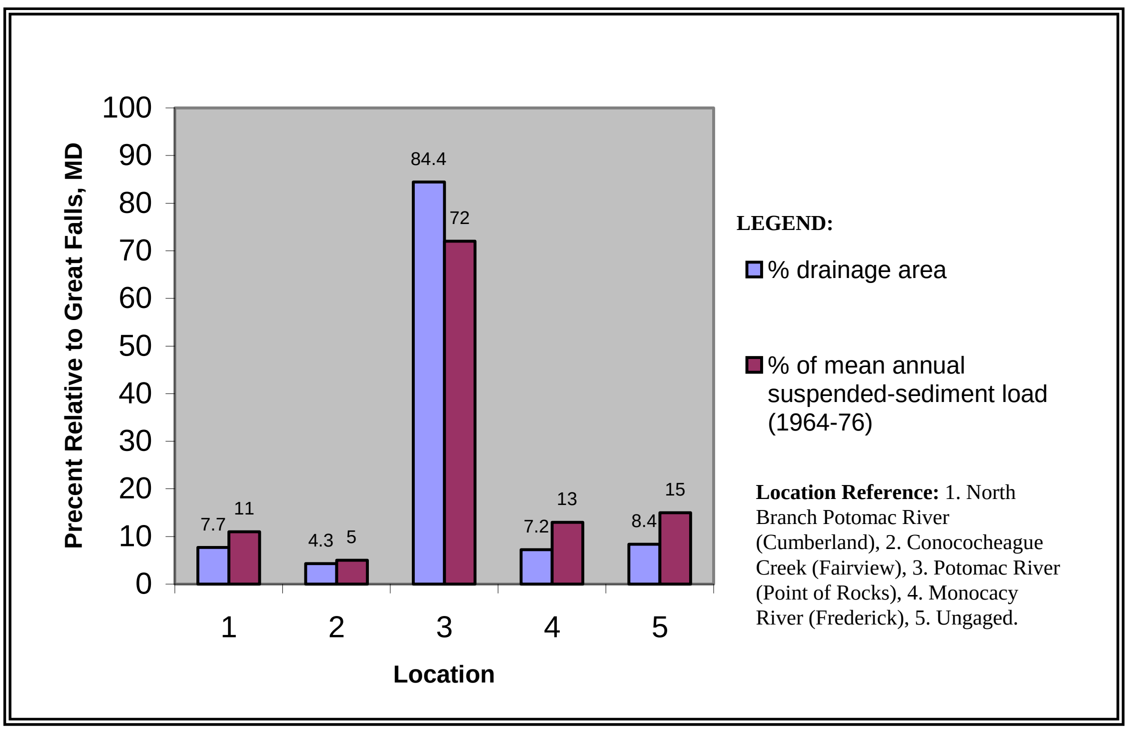


Figure 7. Relative contribution of sediment load (1964-76) by sub-basins above Great Falls, Maryland (modified after Feltz and Herb (1977)).

Contamination of surface water and ground water by pesticides is a major concern to human aquatic health. Between 1993 and 1996, selected pesticides and degradation products were analyzed in 279 water samples collected from 112 stream sites in the Potomac River Basin. Sampling locations and the number of compounds detected at each site are presented in Appendix B. Pesticides were detected most frequently in areas with a high percentage of agricultural land use. During this sampling period, ground water samples were also collected from 105 wells in the Potomac River basin and analyzed for selected pesticides and degradation products. Sampling locations and the number of compounds detected at each site are presented in Appendix C. Pesticides were detected most frequently from wells located in the *Great Valley* subprovince (Donnelly and Ferrari, 1998).

Biological Resources

Water resources are especially important to the success of CHOH's flora and fauna. CHOH should seek to perpetuate the native animal life and native plant life as part of the natural ecosystems. "Native" biological resources are defined as all species that as a result of natural processes have occurred, now occur, or may occur in the future on lands designated as National Parks (National Park Service, 2000a). Federal and State listed species (plants and animals) within the park's boundary are listed in Appendix D. The purpose of this list, which excludes planaria, arachnids, and insects, is to begin exposing some of the biological concerns that might serve as indicators to water-related issues.

Baseline data on floral species within the Great Falls area of CHOH is the most complete, with very little floral information existing outside of Great Falls. Also, minimal recent data exist on fauna species for the park (National Park Service, 1996a). Regional information on rare species and communities that is collected and maintained by The Nature Conservancy and the network of Natural Heritage programs - conservation status and trends, analysis of threats, management needs, natural history - is the most comprehensive such collection of data in the world. The NPS should continue to take advantage of its unique partnership with The Nature Conservancy, fostered through cooperative management of the District of Columbia Natural Heritage Program, to ensure that parks like CHOH take fullest advantage of this invaluable source of information (National Park Service, 1999).

<u>Fauna</u>

The park lists over 30 rare or endangered animals (National Park Service, 1996a). According to Feller (1997), CHOH is the single most important tract of land with regards to the preservation of rare, threatened and endangered subterranean macroinvertebrates in Maryland. Habitat on or immediately adjacent to CHOH make up the majority of occurrences, including diversity, for aquatic subterranean species in Maryland.

All occurrences of aquatic subterranean macroinvertebrates within the CHOH boundary prior to 1992 are recorded in the Heritage & Biodiversity Conservation Programs Database (Maryland Department of Natural Resources). A subsequent study by Feller (1994) documented the distribution of subterranean macroinvertebrate fauna in the western Washington county, Maryland, section (karst region) of CHOH. Feller (1997) also documented a macroinvertebrate survey effort within the Piedmont and Blue Ridge physiographic regions of CHOH.

A limited water quality assessment and biological survey of benthic macroinvertebrates was conducted in 1981 on Antietam Creek. The purpose of this study was to determine if water quality of the creek was supporting adequate benthic macroinvertebrates for sustaining a healthy game fish population. One of the 4 sampling sites (Funkstown Bridge station) contained "questionable" water quality conditions based on dominate pollution-tolerant species (i.e., sow bug (*Asellus*)) identified in the creek (Elliott and Montgomery, 1981).

An amphibian inventory was conducted in 1998 on the lower 60 miles of CHOH (Forester, 1999). Based on this survey, which was during a record drought, the status of the amphibian fauna appeared to be in excellent shape. Nevertheless, several species are poorly represented and warrant a more intensive survey protocol to assess their status (Table 2). After conducting an amphibian inventory (C&O miles 60 – 184.5), Thompson (2000) concluded that C&O Canal is very important to the conservation and continued existence of many species of amphibians, and some reptiles, in western Maryland. Aquatic habitats that warrant special protection according to Forester (1999) are the 1) field pond complex north of C&O mile post 43.2, 2) Bear Island, 3) extensive ephemeral pond at C&O milepost 15.5, 4) Potomac floodplain east of Monocacy Aqueduct, and 5) Great Falls to Seneca Creek along C&O Canal. Several sections of the canal support continuous populations of some species over relatively long expanses of habitat. The best areas have continuous suitable upland habitat, as well (Thompson, 2000).

Table 2. Amphibian species poorly represented or not found during the 1998-99 survey on lower 60 miles of CHOH (Forester, 1999).

Upland Chorus Frog[1]	*Pseudacris t. feriarum*
Northern Cricket Frog[1]	*Acris crepitans*
Southern Leopard Frog[1]	*Rana utricularia*
Northern Leopard Frog[2]	*Rana pipiens*
Green Treefrog[2]	*Hyla cinerea*
Mud Salamander[2]	*Pseudortiton montanus*
Northern Red Salamander[1]	*Pseudortiton ruber*
Four-toed Salamander[1]	*Hemidactylium scutatum*
Purple Salamander[2]	*Gyrinophilus porphyriticus*
Red-spotted Newt[2]	*Notophthalmus viridescens*
Marbled Salamander[1]	*Ambystoma opacum*
Jefferson's Salamander[1]	*Ambystoma jeffersonianum*

Note: [1] identified during survey (incl. larvae) in low population densities.
[2] not identified during survey.

The dwarf wedge mussel (*Alasmidonta heterodon*) was placed on the endangered species list in 1990 when there were only 377 organisms known to exist. The remaining populations are believed to occur in Maryland (including CHOH), New Hampshire, and Vermont. Siltation is a major reason for the decline. Road construction, agriculture, forestry, and removal of riparian vegetation are all causes of this harmful effect. Water pollutants (i.e., pesticides, metals, chlorine, nutrients) and competition from other exotic species (i.e., Asian Clam (*Corbicula fluminea*)) also impact the mussel population (Seavolt, 1999)(MacIvor *et al*., 1995). CHOH, in cooperation with the Maryland State Heritage Program and the USGS Biological Resources Division, is studying ways to minimize the impacts of canal restoration and maintenance activities on freshwater mussels.

A freshwater unionid mussel survey was conducted by MacIvor *et al*. in 1994-95 along C&O Canal, Potomac River, and adjacent tributaries. Of the 153 sites surveyed, the Asian Clam was present at 130 of the sites. Since most freshwater mussels that occur in CHOH require shallow and oxygenated water to survive, the sections of canal where mussels are found could indicate management approaches for enhancing habitat at other sections of the canal. Because most Atlantic Slope freshwater unionids require a fish host to complete their life cycle, further pressures have been placed on mussels due to declining fish populations (MacIvor *et al*., 1995).

Looking at freshwater fish, the Potomac drainage has 61 native, 30 introduced, and 11 diadromous or estuarine taxa (Jenkins and Burkherd, 1993). The paucity and erratic distributions of Coastal Plain species, downstream from Great Falls, is a result of limited suitable habitat. Large streams are absent, other than the estuarine part of the Potomac River and its drowned tributaries. Great Falls is the largest physical main-river barrier (24 – 27 m) of natural origin in Virginia. It is insurmountable to fishes at low and normal river levels. However, during major floods, when the falls are fully submerged, fish can bypass it by swimming through the trees (Jenkins and Burkherd, 1993). Introduced and established fishes make up 33% of the Potomac freshwater taxa, the highest such percentage among major central Atlantic slope faunas. An expanding human population and the scarcity of sizeable species provided a strong impetus for stocking. Apparently the only native, upland, or montane freshwater fishes present and valued as game or food were chain pickerel, white catfish, yellow and brown bullheads, brook trout, pumpkinseed, redbreast sunfish, and yellow perch (Jenkins and Berkherd, 1993).

Fisheries have shown a steep decline in the Chesapeake Bay watershed over the years. From 1965-85, the decline in commercial landings has decreased by 80% or more. This decline is the result of a combination of factors -- some natural, most man-made -- including pollution and siltation of spawning areas, overharvesting by commercial and recreational fishermen, and construction of dams and other obstructions across streams and rivers which prevent access to historic habitat (Chesapeake Bay Foundation, 1991).

A 5-year fish survey (1986-90) was conducted at Little Pool, a 27-acre impoundment just east of Hancock in Washington County, Maryland (Enamait *et al*., 1990). A total of 17 fish species were collected. Water temperature and dissolved oxygen profiles indicate that Little Pool will support a warmwater fishery (Enamait *et al*., 1990). Ecological surveys, which included assessments of habitat and surveys of fish, benthic-macroinvertebrates and algal communities, were conducted in 1993 at nine locations in the Potomac River Basin, as part of the multidisciplinary approach of the U.S. Geological Survey's National Water Quality Assessment (NAWQA) program. A fish survey of the Lower Potomac River Drainage was initiated by the Washington Biologists Field Club in 1995. The survey included a portion of C&O Canal in the vicinity of Plummers Island (study area approximately 283 km^2). Eighty-five fish species were recorded from the study area with 29 species (35%) representing possible or certain introductions of non-native species (Starnes, 1999).

Flora

As of 1995, there were 1577 species of vascular plants identified for CHOH. This listing includes over 160 state rare or endangered plants. Currently Harperella (*Ptilimnium nodosum*) is the only federally listed endangered species in the National Capital Region. A comprehensive list of plant species is presented in the CHOH Resources Management Plan (National Park Service, 1996a).

WATER RESOURCE ISSUES

The park's water-related issues presented in this section were identified during a three-day information-gathering effort in CHOH by the author, extending to numerous follow-up telephone calls after departing the park. Along with a technical literature review, information sources included interviews with NPS management and other federal and state agencies.

Baseline Inventory and Monitoring

To effectively manage natural resources, inventory and monitoring activities should integrate into the overall natural resources planning and management process. Information obtained from these activities better assists the NPS toward understanding how the various environments in a park unit function naturally, and help isolate anthropogenic changes. According to the NPS*, Natural Resources Inventory and Monitoring Guideline* (NPS-75), NPS units have the primary responsibility for implementing inventory and monitoring programs. CHOH should define, assemble, and synthesize baseline inventory data describing the park's water resources under its stewardship and should monitor key aspects of these resources, including interrelationships with visitor carrying capacities at regular intervals to detect changes that may require intervention, and to provide reference points for comparison with other environments and time frames. The collection of adequate information and data to support planning and the analysis of impact of environmental resources, including cultural resources, will precede any final decisions about the preservation or treatment of natural resources (National Park Service, 2000a). CHOH's current status of baseline information for natural resources management does not meet the minimal level (Phase I) established by NPS-75 (National Park Service, 1996a).

Nutrient data collected between 1970 and 1990 indicate that total phosphorus concentrations in the Potomac River at Washington D.C. have decreased since 1979 (Altor *et al*., 1998). Although encouraging water quality trends such as this exist, there are many other alarming problems related to water quality that warrant further monitoring and assessments. For example, mercury contamination from an industrial source in Waynesboro, VA, illustrated in Figure 8, has led to widespread contamination of the Shenandoah and Potomac rivers (Gerhart and Blomquist, 1992). Fisher (1995) identified several Potomac River tributaries that contained measurable concentrations of herbicides. The highest concentrations of atrazine, simazine, metolachlor, and prometon were generally found in streams draining the most intensively cropped parts of the basin, including Conococheague Creek, Monocacy River, Antietam Creek, and the Shenandoah River. A pilot project was undertaken in 1992 to measure physical, chemical, and biological components of eight streams within the Palisades District. Some water quality data were obtained; however, this program was suspended because of staffing needs.

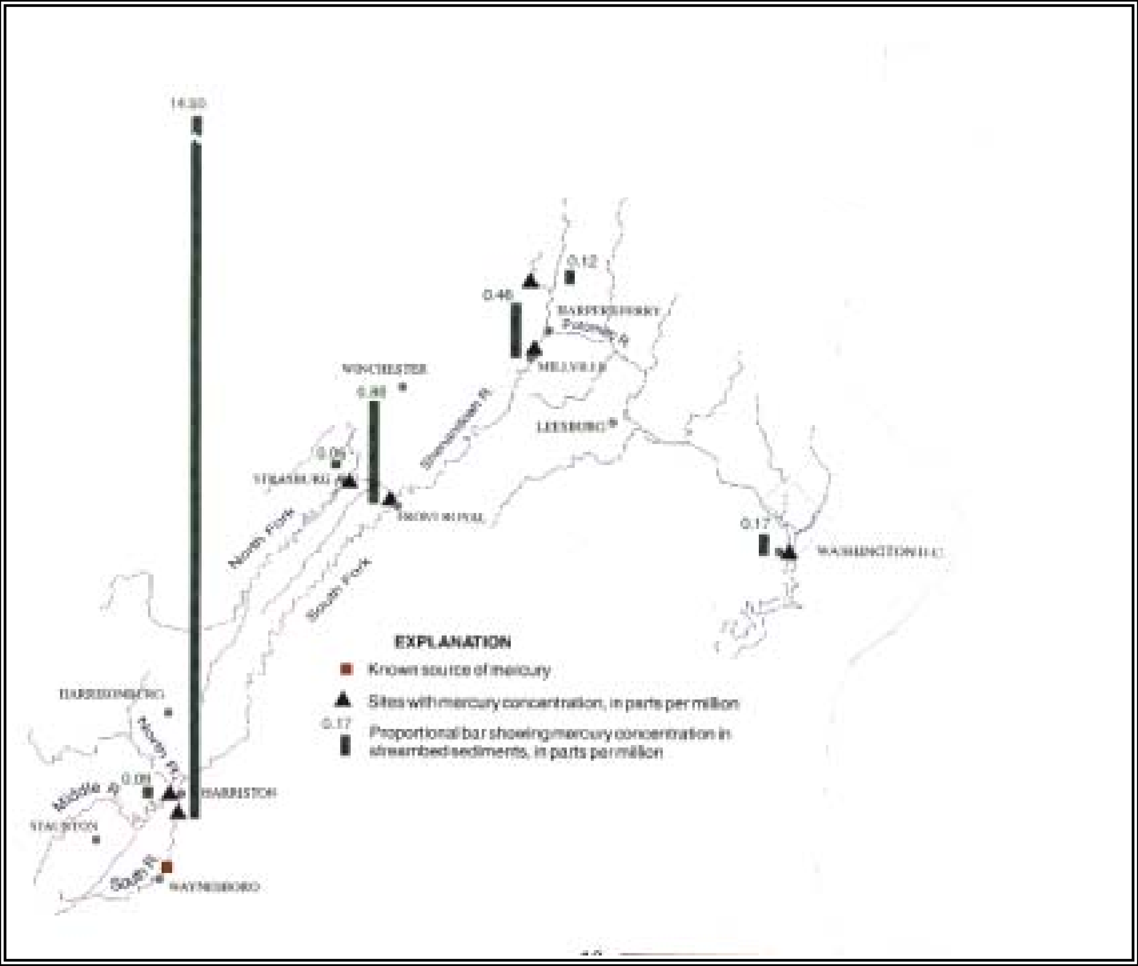


Figure 8. Sampling sites with high concentrations of mercury in streambed sediments downstream from a known source of mercury contamination in Waynesboro, Virginia (Gerhard and Blomquist, 1992).

To complement aquatic subterranean macroinvertebrate surveys at CHOH, baseline water quality data should be acquired at the highest priority conservation sites identified in the survey, such as Glen Echo Heights Quarry Springs. Quarterly water sampling over a 1-year period and analyzed for heavy metals, chlorine, nutrients, suspended solids, dissolved oxygen, and fecal coliform is recommended by Feller (1997). Annual water quality monitoring should be performed thereafter. When possible, water temperature and flow rate should be measured during each sampling event. Event sampling (i.e., immediately after significant precipitation events) would be the best possible indication of water quality, if economically feasible (Feller, 1997).

As mentioned earlier in the report, the NPS Water Resources Division completed a comprehensive summary of existing surface-water quality data for CHOH, *Baseline Water Quality Inventory and Analysis, Chesapeake and Ohio Canal National Historical Park*. The information contained in this report represents data retrievals from six EPA national databases (National Park Service, 1996b). This report should serve as the foundation for baseline water quality data collected at CHOH.

CHOH is in the process of developing a Geographic Information System (GIS) program, with a full-time GIS Program Coordinator on staff. The program is actively inventorying available spatial data on the park and developing resource data theme needs. The U.S. Geological Survey maintains a GIS program to support the Potomac River Basin's National Water-Quality Assessment (NAWQA) program. Geographic-data layers from various sources have been developed for the NAWQA program to help facilitate interpretation of water-quality data collected from the basin (Brakebill, 1994). CHOH's GIS program is working to incorporate existing GIS data layers, along with park-specific data themes to help fuel some of the park's management needs for water resources.

Flood Management

When possible, protection of stream features should be primarily accomplished by avoiding impacts to the floodplain and by allowing natural fluvial processes to proceed unimpeded. This type of management at CHOH is impossible since 85% of the NPS lands, including historical structures, lie within the 50-year floodplain of the Potomac River. As a result, flooding has plagued CHOH throughout its history and floods will continue to plague this NPS unit in the future.

Floodplains in parks should be managed in accordance with *Executive Order 11988* (Floodplain Management) and *Special Directive 93-4: Floodplain Management Guideline*. For NPS units like CHOH, where relocation of existing infrastructure and operations is typically not a viable alternative, flood conditions and associated hazards must be quantified as a basis for decision-making, and appropriate mitigative actions must be taken. Structures and facilities that must be located in floodplains require designs consistent with the intent of the *Standards and Criteria of the National Flood Insurance Program* (44 CFR Part 60). When conflicts between infrastructure (e.g., aqueducts, bridges, canal) and stream processes are unavoidable, NPS management should use techniques that are visually non-obtrusive and that accommodate natural processes to the greatest extent possible. A Statement of Findings must be prepared for actions to be located in a floodplain (National Park Service, 2000a).

Flood-related destruction along the Potomac River is often highly variable due to differences in gradient, channel sinuosity, channel width and channel depth, along with channel obstruction. Depending on the characteristics of a flood event, each flood impacts CHOH's resources differently producing flood damage at different locations in the park (Ingram, pers. comm., 2001). Maximum damage is most probable along stream sections where flood velocities are high, especially during debris-choked events of long duration (Yanosky, 1982). Two locations along C & O Canal notorious for flood-related damage are Harpers Ferry, WV, at the confluence of the Potomac and Shenandoah rivers, and "Widewater", between Great Falls and Old Angler's Inn.

In 1996, hydrologists from the NPS Water Resources Division and National Capital Region observed the flood damage that C & O Canal experienced from the January 20, 1996 flood (Smillie and Curtis, 1996). From this flood evaluation, three different mechanisms of canal erosion and failure were identified; 1) towpath breaching caused by river flow entry into the canal with longitudinal erosion caused by high velocity flow down the canal and breaching downstream in areas of canal discharge back to the river, 2) failure of a stop-lock in conjunction with a road crossing of the canal which impeded flow, and 3) entry of tributary flow into the canal related to the problem of conveying flow under the canal through a culvert at times of high river stage. Smillie and Curtis (1996) concluded that understanding the grade of the river and canal segments explains why the canal is overtopped by high river inflows at certain locations. The canal's grade was constructed to be less than that of the river to allow for a very low velocity flow so canal boats could be towed in either direction. The canal remains close in elevation to the river by a series of locks that were constructed to raise or lower barges to "catch up" with the elevation gain or loss that the river experienced since the previous lock. The effect of this configuration is that between two locks, the upper portion of each canal segment is closer to the river elevation than lower portions of the same segment. Therefore, when flood waters rise in the Potomac, canal flooding begins in the upper portion of the segment first while the lower portion of the segment remains above flow, thus creating rapid flow laterally over the towpath and high velocity flow down the canal. When the high velocity canal water encounters a constriction created by the next downstream lock structure, the water surface becomes elevated and finds the lowest elevation of the towpath in this area and discharges perpendicularly over the towpath back towards the river.

Still trying to recover from the devastating effects of the January flood, CHOH was dealt another blow eight months later when Hurricane Fran delivered rainfall that produced a second flood event comparable to the January flood in water volume and flow velocity. This second flood struck on September 8, 1996. Parkwide assessments following the September 1996 flood revealed damages totaling $65 million to more than 800 structures throughout the park.

The NPS has a responsibility through the enabling legislation to preserve the C & O Canal and other historic cultural features for future generations to enjoy. In response, CHOH has spent millions of dollars repairing and protecting the canal from floods. For example, CHOH is spending $5.5 million to restore the Monocacy River Aqueduct. A primary issue for the aqueduct is structural design and routine maintenance that addresses the natural debris that continually accumulates along the upstream side of the aqueduct (Copenhaver, pers. comm., 2000). During flood events, woody debris can obstruct the aqueduct arches, which accommodate river flows beneath the structure. This can result in localized flooding, accelerated erosion, and structure-threatening stresses on the aqueduct. A similar issue exists with the Conococheague Creek Aqueduct (Bricker, pers. comm., 2000). In 1971 Seneca Creek flooded, carrying houses, boats, trees and debris that were torn loose upstream, and eventually slammed against the Seneca Creek Aqueduct (AJT Birmingham Engineers, Inc., 1988). As a result, the west arch of the aqueduct collapsed. There has been some success with expenditures, such as the bulkheads on Dams 4 and 5. However, the devastation of CHOH after the 1985 and 1996 floods show the Potomac River is winning the battle. Neglect of flood preventative measures and routine mitigation will result in the loss of many historic features in the park. This was demonstrated between 1924 and 1938 when the previous canal owner, B & O Railroad, neglected routine flood-related maintenance and flood prevention measures. The result was the C & O Canal being reduced from a functional waterway to an unsightly wreck (Shaffer, 1997). CHOH revised their Flood Recovery Plan in 1997 (National Park Service, 1997), which serves as a guide for park staff, consultants, cooperators and others in establishing program priorities, repair needs, and schedules for implementation. The plan has incorporated input from the public and other agencies.

Along with property damage associated with flood events, public safety issues are another concern. To reduce the occurrence of accidental drowning in the vicinity of Great Falls of the Potomac River, the NPS established a computer-based real-time warning system that alerts park management and river safety personnel to imminent hazardous conditions (Reed *et al*., 1990).

Minerals Extraction

The North Branch Potomac River receives acid mine drainage from as many as 11 of its tributaries which drain the coal mining region in West Virginia (Baloch *et al*., 1973). Coal has been mined in this part of the Potomac River basin for about 150 years. The breakdown of pyrite (iron sulfide) associated with coal, upon exposure to air and water by mining, leads to the formation of sulfuric acid. The acidic water is able to hold in solution high concentrations of iron, manganese, and aluminum. This has resulted in sections of the North Branch Potomac River and many of its tributaries failing to meet Maryland and West Virginia water quality standards. Some reaches of North Branch and its tributaries are virtually devoid of aquatic life. Acidic and highly mineralized water tend to persist for long distances despite some deposition on the stream bed. In 1966, low pH values (3.3 – 3.6) were recorded at Cumberland, MD after heavy rains, which caused an extensive fish kill downstream (Trainer and Watkins, 1975). There are plans to rewater C&O Canal at Cumberland, MD, which elevates the water quality concern. Abar (1978) estimated the cost of abating mine drainage in the entire Potomac River Basin to exceed $100 million.

In 1965, the NPS acquired a 650-acre tract adjacent to Great Falls that was originally mined for gold. Gold was discovered on this tract in 1861 and mined until 1951, yielding more than 5,000 ounces. Today, the area is laced with abandoned mine shafts of varying depths and geometry along a slope that a drains toward the canal and Potomac River. Dr. Schumway at Frostburg State University is currently evaluating changes to vegetation in the mining area (Sauter, pers. comm., 2000). Complementary efforts, such as hydrogeological and water chemistry assessments, should be encouraged since this area receives extensive visitor use and mining-related impacts (e.g., water contamination) may exist.

Agricultural Use Management

Approximately 1400 acres in the park are under agricultural use permits. Agricultural activities consist of hay, corn, and cattle production. To better manage these activities within the sensitive habitats (e.g., wetlands, floodplains) which they are located, CHOH has implemented some best management practices (BMPs). For example, at one of the permitted fields, water for cattle is collected from a tributary at the edge of the field and gravity fed to a trough. This practice prevents the need for cattle to access the fragile riparian lands along the Potomac River, except during extreme dry conditions when the tributary no longer has surface flow. In this particular case, CHOH may want to consider installation of a ground water well in the field, which would provide a dependable water supply year round and prevent the need for cattle to access the river at any time. This effort would also support the NPS Chesapeake Bay Riparian Buffer Plan. The plan challenges NPS units located in the Chesapeake Bay watershed to restore 35 miles of riparian forest buffers within NPS units located in the Chesapeake Bay watershed before 2010 (National Park Service, 1998b).

Recreational Management

More than 3 million visitors annually enjoy the natural setting and rich history offered by CHOH (National Park Service, 1997). Public water supplies (well pumps) maintained by CHOH are sampled from mid-March through mid-November at the hiker/biker campgrounds. All well pump handles are removed during the off-season, and placed back on the pump in April after two water samples are tested and determined to be free of contamination.

Monthly water sampling is conducted by NPS staff at the following CHOH sites:

Palisades:	Swains Lock Seneca
Monocacy:	Monocacy shop
Conococheague:	Ferry Hill headquarters Bussard property ranger station
Four Locks:	Weber property Baker property Lockhouse 49
Paw Paw:	Oldtown maintenance shop Moore property

Annual testing is conducted in August at the following CHOH sites:

Palisades:	West property at Seneca
Monocacy:	Chick Farm Shores property Myers property
Conococheague:	Burnside property Barr House

Evidence suggesting sewage contamination impacting C&O Canal has been documented (Forester, 1999). During a 1998-99 amphibian survey along the 8 miles between Great Falls and Seneca Creek, a distinct raw sewage odor appeared to be emanating from the canal. This section of the canal is located where large homes are built on the bluff overlooking the canal and Potomac River. This is also the approximate location for the Dulles/Interceptor sewer vent (Ingram, pers. comm., 2001). If it is determined that the sewer vent is not the odor source, a water quality assessment of the canal waters should be implemented. If waters were found to contain high bacteria and/or nutrient concentrations, dye tracing of local septic systems may be warranted in an attempt to identify the point source(s). At a minimum, CHOH would need to warn the public if a health problem exists here.

At Oldtown, fishing within the canal prism is a popular recreational activity for visitors and locals. This particular site has become a management challenge for CHOH in that aquatic plants (both native and exotic) aggressively cover the canal water, minimizing open water areas conducive for fishing. The park manages the aquatic vegetation with a mechanical harvester on an “as-needed” basis. Aquatic vegetation is also a problem in other sections of the canal. For example, submerged aquatic vegetation (hydrilla) clogs the water canal section in Georgetown where the interpretive canal boat is in operation.

At McMahon’s Mill, the Potomac River is used in place of the canal. A dam (Feeder Dam 4) backs water on the Potomac at this location, which allowed the canal boats to easily travel in the river along the towpath. The original towpath immediately downstream from the mill is severely wash out and closed to visitors. A temporary detour around this closed section of towpath is in place. CHOH is pursuing three avenues to address this problem: 1) make county roads used in the temporary detour safer for visitors (i.e., better signage), 2) work with adjacent landowners for an interim by-pass off of county roads through some upland karst features closer to and within the park, and 3) use NPS funding procedures to obtain Congressional appropriations to restore the towpath (Ingram, pers. comm., 2001). Boardwalks and other “light-on-the-land” methods should be considered as design options on the interim detour since elevated walkways would provide visitor protection and minimize natural resource impacts (i.e., protect recharge areas, sensitive cave habitat, and flora).

Wetlands Management

Fragmentation and development pressures are degrading wetlands around and inside CHOH. An estimated 1.2 million acres of wetlands occurred in Maryland before European settlement, but that number is now reduced to 600,000 acres. Approximately 57% (342,000 acres) are non-tidal palustrine wetlands. Maryland has lost over 600 acres of these wetlands each year since 1955 (Thomson *et al*., 1999). The natural disturbance of flooding, past land use, and general landscape fragmentation promotes the occurrence of some invasive non-native species. For example, *Microstegium vimineum*, *Lonicera japonica*, and *Alliaria petiolata* are non-native plant species identified at Bear Island, Dickerson Floodplain, and Cabin John Island that threaten native community composition and species diversity (Thomson *et al*., 1999).

CHOH is required to preserve natural wetland characteristics and functions, minimizing wetland degradation and loss, and avoiding new construction in wetlands. The NPS implements a "no net loss of wetlands" policy. *Executive Order 11990* directs the NPS: 1) to provide leadership and to take action to minimize the destruction, loss, or degradation of wetlands; 2) to preserve and enhance the natural and beneficial values of wetlands; and 3) to avoid direct or indirect support of new construction in wetlands unless there are no practicable alternatives to such construction and the proposed action includes all practicable measures to minimize harm to wetlands (National Park Service, 1998a).

One impediment to wetland protection and restoration efforts is the lack of adequate benchmarks to assess ecological integrity. The health of a wetland system is difficult, if not impossible to assess without explicit knowledge of the target community (Thomson *et al*., 1999). *Director's Order 77-1*: *Wetlands Protection* requires the NPS to conduct or obtain wetland inventories within each park unit. Presently, CHOH does not have an adequate inventory of wetlands within its boundaries to assist proper NPS planning with respect to management and protection of wetland resources. It is important for the NPS to establish baseline wetland information (i.e., target communities) to assist with separating anthropogenic impacts from natural processes. When natural wetland characteristics or functions have been degraded or lost due to previous or on-going human actions, the NPS will, to the extent practicable, restore them to pre-disturbance conditions (National Park Service, 2000a). National Wetland Inventory maps (1:24,000) are on-file within the park; however, they do not show the detail necessary to adequately protect the wetland resources within the park. More detailed wetland inventories were started in 1991, but suspended because of lack of staff time and expertise (National Park Service, 1996a).

Hazardous Waste Management and Spill Contingency Planning

For most NPS units like CHOH, internal NPS operations require that hazardous substances, such as petroleum products used by maintenance operations, be stored and handled on a routine basis. Although it is the goal of the NPS to minimize releases of these substances into the environment, accidental releases still occur. The action of those employees who first encounter contamination in the park could well determine the severity of the impact(s) on human health and the environment. Therefore it is important for NPS staff to understand the basic requirements for response to hazardous substance spills.

An even greater concern for hazardous spills in the park exists from external operations. A number of transportation corridors such as Interstates (e.g., I-70, I-81), state and county highways, as well as active railroads, can be found within or adjacent to the park. Trucks and rail cars carry fuel oil, diesel fuel, gasoline, and a variety of agricultural and industrial chemicals along these corridors. In addition to road and rail traffic, CHOH is located adjacent to several major cities and towns (Cumberland, MD; Williamsport, MD; Harpers Ferry WV; Brunswick, MD; and Georgetown, D.C.) where numerous storage areas exist for materials associated with agricultural and industrial operations. Given the potential pollution pathways, accidental release of hazardous materials is a continuous threat to CHOH's natural resources.

The NPS is severely limited in qualified personnel, spill response equipment, and baseline natural resource information to effectively respond to and evaluate impacts from hazardous spills in CHOH. Emergency response to a major spill requires expertise and field equipment that extends beyond the capabilities of the NPS. In accordance of the National Contingency Plan established under the Clean Water Act, federal agencies are required to have a Spill Contingency Plan (SPC) for emergency response to any spill of oil or hazardous substances for which they are responsible. Furthermore, a Spill Prevention Control and Countermeasure Plan (SPCCP) is required for the NPS to maintain compliance with 40 CFR 112 (EPA Regulations on Oil Pollution Prevention). Hazardous waste reduction programs are also required by the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Act Amendments of 1984 and Title III of the Superfund Amendment Reauthorization Act (SARA Title III).

Currently, CHOH does not have a SCP or SPCCP. The park manages aboveground diesel tanks to fuel NPS equipment. According to CHOH maintenance staff, these tanks comply with the latest regulatory requirements (e.g., double-walled, etc.). Gasoline for park operations is obtained from local private facilities. It is important for the park to establish an internal communication process through planning documents (i.e., SCP and SPCCP) to maintain compliance with hazardous waste management and spill contingency planning. The result is in a safer environment created for park staff and visitors.

In Brunswick, MD, a CHOH canal construction and rewatering project has been terminated due to soil and ground water contamination. An environmental site assessment conducted by Ecology and Environment, Inc (E & E) in 1995-1996 concluded that the known contamination with petroleum products found on the CSX site is migrating onto NPS property (Ecology and Environment, Inc., 1997). Continued negotiations with CSX, Maryland Department of the Environment, EPA and the NPS have not resolved a mitigation plan agreeable to all parties. As deliberation continues, field data shows contaminate levels increasing on NPS property (Ecology and Environment, Inc., 1997).

Property was purchased by CHOH in Williamsport, Maryland that may have contamination problems based on historic use. The property includes 10 sedimentation ponds previously owned by the Garden State Tannery, which is still in operation in Willamsport. According to CHOH staff, minimal environmental assessment information has been identified by the NPS for the property (Conway, pers. comm., 2000). It should be a priority for the NPS to seek professional expertise to adequately assess the "health" of this property. These sedimentation ponds could represent hazardous sites that require time-sensitive mitigation.

In 1981, aniline, a volatile toxic compound, was accidentally released into the Potomac River upstream of Shepherdstown, WV. Although the released quantity was small and the downstream concentrations did not threaten the aquatic communities or potable water supplies, the event did underscore the need for effective management of toxic spills. In response, The Interstate Commission on the Potomac River Basin developed a toxic spill model for the Potomac River Basin to begin an effort in estimating the fate of spill material so that downstream industrial and water supply utilities may be notified in time to take appropriate action. The model was developed based upon time of travel studies performed on selected river reaches in the Potomac River basin (Hogan *et al*., 1986).

More recently, an insecticide (cypermethrin) was released into Rock Creek by an industrial plant located in Silver Springs, Maryland in May 2000. The pollutant flowed downstream and entered the District of Columbia and waters of Rock Creek Park, killing over 100,000 fish. The confluence of Rock Creek is located at Georgetown, the beginning (mile 0) of C & O Canal. It is estimated that it will to take several years before the impacted aquatic communities fully recover (National Park Service, 2000b). Toxic releases like this along C & O Canal are a concern for the NPS, along with other federal, state, and county agencies. CHOH's watershed includes the drainage basin that supports water needs for the Washington D.C. area, along with numerous smaller municipalities located along the Potomac River and it's numerous tributaries (Hogan *et al*., 1986). Some NPS units have introduced products and techniques that improve the quality of spill response. For example, Mammoth Cave National Park developed a hazardous spill map book (Hazmap) of each of the three transportation corridors that traverse the park's sensitive karst watershed (Fry and Meiman, 1994). These maps identify flow paths for existing drainage structures and hydrologic features with identifying landmarks along the two highways and one railway. Now when a toxic spill occurs, emergency responders use the "Hazmap" for developing quick and prudent decisions, which may avert a catastrophe within the cave system. A similar effort would complement other CHOH needs. For example, Feller (1994), in working in CHOH's karst area, expressed the need for hydrogeological assessments to define recharge boundaries for individual springs and caves that support sensitive macroinvertebrate species. Additional protection could then be implemented within these boundaries, as needed, to protect sensitive subterranean habitat.

Water Rights

The Potomac River has for centuries been a site of recreation, fishing, and, increasingly important, a source of water. Provision for an adequate water supply to a sprawling Washington metropolitan area is a major issue in the Potomac River Basin. The various states and the District of Columbia have diverse laws and sometimes conflicting interests with regards to water usage. The rapid growth of population and economic activity since World War II has led to large increases in water withdrawals. The quality and quantity of Potomac River waters available for consumptive and other uses will be determined by activities throughout the river basin. Many of these activities are now subject to regulation by the federal government (Interstate Commission on the Potomac River Basin, 1976). In 1978, the Potomac River Low Flow Allocation Agreement was developed to provide an interjurisdictional mechanism for allocating water among the various Potomac water suppliers during periods of critical low flow. The portion of the Potomac covered by the "Agreement" extends from Little Falls Dam to the farthest upstream limit of the pool at Seneca, Maryland (Maryland Department of Natural Resources, 1981).

Since water from the Potomac River is used to recharge C & O Canal at various intake sites along the canal, exceptionally low river flows could adversely affect the canal's historical structures, recreational activities, and local aesthetics. For example, the canal's historical structures (i.e., wooden locks, gates, weirs) will deteriorate quickly if exposed to air or to repeated wetting and drying (Maryland Department of Natural Resources, 1981). In response to these concerns, water for the preservation and management of CHOH will be obtained and used in accordance with legal authorities. The Interstate Commission on the Potomac River Basin is currently updating the 20-year water demand forecast (water budget) for the Potomac River. While preserving its legal remedies, the NPS should work closely with the regional water administrators to protect park resources, and participate in negotiations to seek the resolution of conflicts among multiple water claimants (National Park Service, 2000a). According to the CHOH engineer, approximately 20-34 ft^3/sec (cfs) is taken from the Potomac River and used to recharge the C&O Canal at Violettes Lock. At Swains Lock, approximately 7-10 cfs is returned to the river and at Great Falls, approximately 7 cfs is returned to the river. So by Widewater, approximately half of what was taken from the Potomac River is returned. Below Little Falls, the remaining water taken from the river is returned (Ingram, pers. comm., 2000).

Coordination

Activities that take place outside park boundaries and not under NPS control sometimes have a profound effect on the ability to protect park water resources and values. In recognition, the NPS is committed to working cooperatively in the management of natural resources with federal, state, and local agencies; Native American authorities; user groups; adjacent landowners; and others. The NPS will seek to establish communication and consultation to better achieve park management objectives and protection of natural systems and values (National Park Service, 2000a). Recognizing that cooperation with other land managers can accomplish ecosystem stability and other resource management objectives when the best efforts of a single manager might fail, CHOH should develop agreements with other land managers when appropriate to coordinate natural resource management activities in ways to improve, not compromise, park resources.

Water resource partnerships in the Potomac River watershed are summarized in a report prepared by the National Park Service (1995). These partnerships provide a valuable resource for CHOH in expanding NPS conservation efforts and complimenting existing water resource programs. These partnerships include:

1. The Interstate Commission on the Potomac River Basin (ICPRB), established in 1940, was one of the first organizations in the nation established to coordinate water resources efforts on a regional scale. In 1970, the ICPRB was expanded to include all water and water-related land resources in the basin, as well as water quality.

2. During the past two decades, the nationally-recognized Chesapeake Bay restoration efforts have strengthened and expanded cooperative restoration and conservation activities in the Potomac River basin, including CHOH. The 1983 and 1987 Chesapeake Bay Agreements and the 1992 Amendments represent a strong partnership between the citizens and the federal, state, and local governments.

3. The U.S. Geological Survey has maintained a water quality assessment program, National Water-Quality Assessment (NAWQA), for the Potomac River Basin since 1991. The USGS maintains several water-quality monitoring sites on the Potomac River and selected tributaries, including numerous ground water monitoring wells.

4. The U.S. Fish and Wildlife Service (USFWS) has the lead responsibility among cooperating federal agencies for restoration of fish and wildlife and their native habitats. The USFWS manages three national wildlife refuges within the Potomac River watershed.

5. The Potomac Watershed Network is a group based at George Mason University whose primary objective is to promote and coordinate education relating to the Potomac River basin. Members work with school science administrators to develop a comprehensive curriculum in watershed ecology for elementary grades through high school. CHOH is currently involved in an educational outreach program, “Bridging the Watershed”, where the target group is high school students.

In the mid-1980’s the U.S. Geological Survey, Maryland Department of Natural Resources, Virginia Department of Environmental Quality, and the Metropolitan Washington Council of Governments established the River Input Monitoring (RIM) program. One objective of this program is to quantify the loads and long-term trends of nutrients and suspended sediment that enter the tidal part of the Chesapeake Bay Basin from its nine river basins, which includes the Potomac River Basin. Results of the RIM program are being used to help evaluate the effectiveness of strategies aimed at reducing nutrients entering Chesapeake Bay from its tributaries (Belval and Sprague, 1999).

The Nature Conservancy and CHOH have joined forces to plan for the conservation of the Potomac Gorge's natural resources. The Gorge is recognized as having one of the highest concentrations of globally rare communities in the nation. The following components to the conservation planning process have been identified: (a) conservation targets (riparian communities, terrace communities, upland forest blocks, tributary stream system, rare groundwater invertebrates, anadromous/semianadromous fish, wetlands), (b) stresses and sources, (c) conservation strategies, and (d) success measures.

The Maryland Biological Stream Survey provides rapid bioassessments, modeled after EPA protocol, to waterbodies in Maryland [Roth *et al*. (1997a) and Roth *et al*. (1997b)]. A biological stream survey for C&O Canal and streams that enter the park is something CHOH staff is interested in pursuing. The purpose of the survey would be to characterize and inventory aquatic habitat located in the park for natural resources management and protection purposes. A CHOH stream survey should include; water chemistry, benthic macroinvertebrates, fish, herpetofauna, aquatic vegetation, mussels, and physical habitat (Ingram, pers. comm., 2001). The park should work with Maryland's Department of Natural Resources to determine what streams, if any, have been surveyed in the park using the Maryland Biological Stream Survey. Coordination should then be initiated with Maryland's Department of Natural Resources to prioritize and survey waterbodies in the park.

Maryland's Stream Corridor Assessment (SCA) Survey is providing a quick way of examining entire drainage networks so future monitoring and management efforts can be better targeted. Over the past several years the Maryland Department of Natural Resources Water Resources Division has been developing and refining the SCA Survey (Maryland Department of Natural Resources, 1999). Over 2000 miles of streams in Maryland have been surveyed, including over $2 million in restoration work. This program seeks partnerships to complement the ongoing efforts (Yetman, pers. comm., 2001). The main goals of the SCA Survey are to provide:

1. A list of environmental problems within a watershed's stream system and riparian corridor,
2. Sufficient information of each problem so that preliminary determination of both its severity and restoration potential can be made,
3. Sufficient information so that restoration efforts can be prioritized, and
4. A quick assessment of both in-stream and near-stream habitat conditions so that different stream segments can be compared.

If a site ranks high for potential management action, a restoration specialist revisits the site to confirm the initial assessment and begin to develop a restoration plan.

Internally, there is no simple mechanism for analyzing or summarizing most natural resources information on a regional, or even multi-park basis. This limits the effectiveness of this information in all aspects of decision support, especially opportunities for funding both staff and projects. Park information needs to be standardized to the degree necessary to allow the quick and easy assembly of regional data sets. Also, all appropriate information should be posted on intranet/internet sites for ease of retrieval (National Park Service, 1999).

RESOURCES MANAGEMENT STAFFING AND PROGRAMS

The CHOH Resource Management Division staff is currently comprised of five permanent positions as indicated in the organizational chart presented in Figure 9. The Chief of Resource Management reports directly to the Assistant Superintendent. Based on the Natural Resource Management Assessment Program (NR-MAP) that evaluates the workload of a NPS unit with respect to natural resources, CHOH should have 56.9 full-time equivalents (FTEs) to adequately accomplish the responsibilities necessary to preserve and protect the natural resources. A graphic example of how understaffed this NPS unit is for properly managing the natural resources, including water.

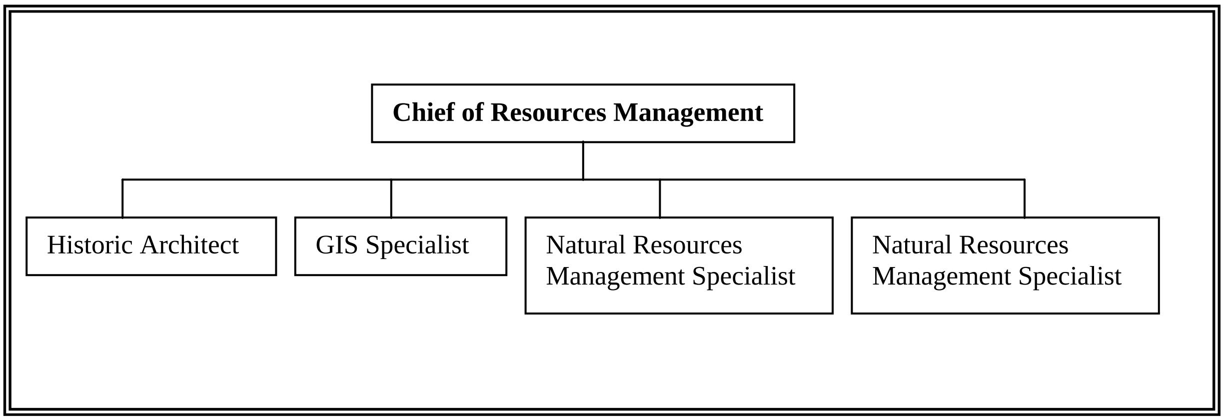


Figure 9. Chesapeake and Ohio Canal National Historical Park, Resource Management Program: Organizational Chart.

Based upon CHOH's Investigator's Annual Reports (IARs) [1993-2000] there have been numerous projects in the park directly or indirectly related to water resources. The following is a select list of these projects. (Note: Some of these projects have been captured in greater detail in this report.)

1. <u>Trophic Lake Assessment</u> (1993-95): Classify all publicly-owned lakes in Maryland, according to trophic condition, based on measurements of secchi depth, total phosphorus, and chlorophyll *a*. Investigator: Morris Hennessey. Permit #: CHOH1993AIMT, CHOH1994AJXQ, CHOH1995AOJG.
2. <u>Field Survey of Reptiles and Amphibians</u> (1993-94): Document all reptiles and amphibians observed by date, species, and locations near Great Falls and on Olmstead Island. Investigator: Ted Kahn. Permit #: CHOH1993AIMU, CHOH1994AJXR.
3. <u>Invertebrate Survey</u> (1993): Identify undescribed species of isopods. Investigator: Arnold Norden. Permit #: CHOH1993AIMV.
4. <u>NCR Phase III Urban Stream Study</u> (1993-95): Determination of extent of impairment of stream resources. Investigator: Michael Sullivan. Permit #: CHOH1993AIMX, CHOH1994AJXT, CHOH1995AOJO.

5. Aquatic Subterranean Macroinvertebrate Survey (1994-95, 97): Survey of ground water springs for baseline inventory (subterranean macroinvertebrates). Investigator: Daniel Feller. Permit #: CHOH1994AJXX, CHOH1994AJYD, CHOH1995AOJE, CHOH1997ASNM.
6. Native Mussel Inventory (1994-95): Identify mussel species for baseline inventory. Investigator: Laurie MacIvor. Permit #: CHOH1994AJXZ, CHOH1995AOJH.
7. Study of Water Quality and Biota of Potomac River Basin – Part of a National Water Quality Study (1994-95): Part of the U.S. Geological Survey's National Water Quality Assessment Program. Investigator: Humbert Zappia. Permit #: CHOH1994AJYC, CHOH1995AOJS.
8. Comparison of Fish Species Found in Historical Study (1995): Seine and net fish found in vicinity of Plummers Island and compare findings to past historic study. Investigator: Wayne Starnes. Permit #: CHOH1995AOJM.
9. Inventory and Monitoring of Muddy Branch, Maryland (1995-97): Inventory and monitoring Muddy Branch, Maryland. Routine collection of water quality samples and monitor stream invertebrates as part of a water quality assessment program. Investigator: Paula Wang (1995-96), Stephanie Mason (1997). Permit #: CHOH1995AOJQ, CHOH1996APXX, CHOH1997ASNQ.
10. Survey for Introduced Populations of Rainbow Darters within C&O Canal NHP and Pennyfield (1997): Inventory and monitor population levels of exotic fishes, specifically rainbow darters. Investigator: Robert Bock. Permit #: CHOH1997ASNL.
11. Inventory of Copepod Crustaceans of Chain Bridge Flats within C&O Canal National Historical Park (1997): Inventory copepod crustaceans, especially *Elaphoidella* (new species) and *Osphranticum labronectum*. Investigator: Janet Reid. Permit #: CHOH1997ASNS.
12. Floodplain Forest Communities of the Potomac Watershed (1997): Gather plot vegetation data in order to classify the various floodplain forest communities. Investigator: Diane Thomson. Permit #: CHOH1997ASNW.
13. Aquatic Survey of Quarry Branch, Chisel Branch, and Cabin Branch Upstream from C&O Canal NHP (1997): Compile a dataset of biological community attributes for the development of an Index of Biological Integrity (IBI) for stream fish and an IBI for benthic macroinvertebrates. Investigator: Keith Van Ness. Permit #: CHOH1997ASNX.
14. Potomac River Basin NAWQA Surface-Water Synoptic Survey of Triassic Lowland Streams (1997): Part of the U.S. Geological Survey's National Water Quality Assessment Program. Sample Algae, invertebrates, and classify habitats as part of the assessment protocol for Broad Run. Investigator: Humbert Zappia. Permit #: CHOH1997ASNZ.
15. Amphibian Survey of the C&O Canal National Historical Park in Allegany and Washington Counties, MD (1998-99): Inventory of amphibian species, abundance, and locations from Cumberland, MD to the Washington County/Frederick County line. Important habitats adjacent to CHOH will also be identified. The primary objective was to identify areas most important for amphibian conservation within or adjacent to CHOH and to identify future monitoring sites for various amphibian species. Investigator: Edward Thompson. Permit #: CHOH1998001.

16. <u>Amphibian Inventory of the Chesapeake & Ohio Canal National Historical Park in Frederick and Montgomery Counties, MD and the District of Columbia</u> (1998-99): Conduct inventory of amphibian species, abundance, and locations from towpath milepost 0-60 covering Frederick and Montgomery Counties. Investigator: Donald Forester. Permit #: CHOH1998003, CHOH1999007.
17. <u>Evaluation of Native Freshwater Mussel PopulationsPopulations in the C and O Canal NHP: Strategies for Integrating Management of Biological with Cultural Resources</u> (2000): Evaluate the status of native freshwater mussels within the park. Determine the genetic population of mussels within the park and adjacent areas of the Potomac River. Evaluate salvage holding and restoring native mussels as a management tool for conservation of mussels within the park. Investigator: Rita Villella. Permit #: CHOH-2000-04.

Addressing the high-priority issues presented in this report requires funding and human resources that greatly exceed CHOH's current Natural Resources program. Partnerships have helped to alleviate some of the inadequate natural resource support. Water-related projects presented in this report represent many hours of hard work by CHOH's staff and the NPS-National Capital System Support Office in forging partnerships with federal and state agencies and universities. CHOH management should work toward expanding their natural resource staff with expertise in water resources. At CHOH, water resource expertise is not a luxury, but a necessity.

RECOMMENDATIONS

The water-related issues and natural resource data presented in this report are supported through regional and local research and monitoring efforts. Identification of available water resource information (i.e., what has or has not been done at CHOH) has also contributed toward exposing the "data gaps", which translates to natural resource needs for CHOH. Some of the water-related needs captured in this report are summarized below:

- Baseline information on water resources.

  - Collect baseline water quality data from high-priority conservation sites to complement CHOH macroinvertebrate surveys (Feller, 1997).
  - Assess water quality impacts, if any, to CHOH water resources from Waynesboro, VA mercury contamination.
  - Complete data-layers for CHOH GIS to fuel some of the park's data management needs for water resources.
  - Collect baseline water quality data at Cumberland, MD to assess water quality impacts from coal mining in the North Branch watershed, since there are plans to rewater the canal at Cumberland.
  - Collect baseline water quality data in the canal at Great Falls to assess impacts, if any, from the 1861-1951 local gold mining operations, since this area has high visitor use.
  - Monitor the following aquatic habitats, which warrant special protection according to Forester (1999): 1) field pond complex north of C&O mile post 43.2, 2) Bear Island, 3) extensive ephemeral pond at C&O milepost 15.5, 4) Potomac floodplain east of Monocacy Aqueduct, and 5) Great Falls to Seneca along C& O Canal.
  - Define recharge boundaries for individual springs and caves that support sensitive macroinvertebrate species.
  - Work with Maryland's Department of Natural Resources to determine what streams, if any, have been survey in the Park using the Maryland Biological Stream Survey. Coordination should then be initiated with Maryland's DNR to prioritize and survey waterbodies in the park.
  - Standardize CHOH's water-related information to allow quick and easy assembly of regional data sets. Post appropriate information on intranet/internet sites for ease of retrieval.

- Flood Management

  - Following the CHOH Flood Recovery Plan (National Park Service, 1997), continue routine flood maintenance of CHOH cultural and park operation structures and implement appropriate flood-preventative design, as needed.

- Agricultural Use Management

  - For the 1400 acres of permitted agricultural use in CHOH, implement best management practices to protect riparian areas and meet the objectives in the NPS Chesapeake Bay Riparian Buffer Plan (National Park Service 1998b).

- Recreational Management

  - Assess water quality (bacteria) of canal waters between Great Falls and Seneca Creek in response to a raw sewage odor reported during 1998-99 amphibian survey.
  - Implement appropriate management techniques where aquatic plants (exotic and native) are impeding the recreational function of the canal (i.e, fishing at Oldtown, canal boat operation at Georgetown). Assess water quality in these areas to determine if waters have become nutrient rich, thus promoting dense growth of aquatic vegetation.
  - Incorporate environmental education into CHOH's interpretive program (e.g., provide educational brochures to visitors and local residents that communicate park management objectives, priority issues (including understandable data that supports the issues), and, if possible, alternatives for reducing environmental threats).

- Wetlands Management

  - Inventory wetlands in the park at greater resolution (larger scale) than the current 1:24,000 National Wetlands Inventory maps.

- Internal Management

  - Prepare a SCP/SPPCP that meets regulatory compliance, to properly address routine facilities operations (i.e., hazardous materials management) and spill response procedures. Provide annual staff "refresher" training to ensure efficient communication processes for emergencies (i.e., spills) and compliance to regulatory requirements.
  - Monitor progress between CSX, EPA, and Maryland Department of the Environment on remediation of soil and ground water contamination at Brunswick, MD.
  - Evaluate existing environmental assessment work on property, including the 10 sedimentation ponds, acquired by CHOH from Garden State Tannery in Williamsport, Maryland. Does this property contain soil and/or ground water contamination?
  - CHOH management should seek additional base funding through the Operation Formulation System (OFS) process to augment natural resources management and water resources protection.

- Water Rights

    - Work closely with regional water administrators to protect park resources and participate in negotiations to seek the resolution of conflicts among multiple water claimants.

- Coordination

    - Continue to develop cooperative agreements with other land managers when appropriate to coordinate natural resource management activities including; Maryland's SCA Survey efforts, RIM program, ICPRB, The Nature Conservancy, U.S. Geological Survey, U.S. Fish and Wildlife Service.

The political and environmental complexity of the park's issues elevates the need to expand upon the information contained in this scoping report by producing a more comprehensive Water Resources Management Plan (WRMP) for the park. A WRMP will provide a more detailed description of the issues presented in this report, while including an overview of existing state and federal legislation that pertains to the park's water resources. The plan will also include recommended actions (project statements) for the park's Resource Management Plan that address these, and possibly other, high-priority issues. Project statement development should build from the natural resource needs outlined in this report. These project statements will define the specific problem(s) and recommended action(s), including a representative budget, that can compete for future internal and external funding calls.

The WRMP process will strengthen existing partnerships and encourage other stakeholders to participate with the NPS during and after plan development. Many of the issues presented in this report extend beyond NPS boundaries; thus, it is important to recognize the fact that multi-agency communication and coordination are essential to successfully manage CHOH's water resources.

The park is encouraged to place a high priority in seeking funds, both internally and externally, to expand its resource management program, and to develop a WRMP. Expansion of the park's Resource Management Division with qualified staff is a critical component to a successful WRMP process. A WRMP will provide only minimal contributions to a park if there is minimal Resource Management staff and expertise to drive the recommendations. It is estimated that a WRMP for the park will take 2 years to complete and cost approximately $50,000. Until a WRMP is prepared for CHOH, components of this scoping report should be used in the development of time-sensitive management strategies and project statements relating to water resource issues.

LITERATURE CITED

Abar, A.F. 1978. The Rising Costs of Mine Drainage Abatement. [In] The Freshwater Potomac, Aquatic Communities and Environmental Stresses. Jan. 1977 symposium proceedings, College Park, Maryland. (eds.) K.C. Flynn and W.T. Mason. Interstate Commission on the Potomac River Basin, Rockville, MD. pp. 109-111.

AJT Birmingham Engineers, Inc. 1988. Evaluation of Feasibility of Flood Damage Mitigation Strategy for the C & O Canal, NHP. Washington D.C.

Ator, S.W., J.D. Blomquist, J.W. Brakebill, J.M. Denis, M.J. Ferrari, C.V. Miller, and H. Zappia. 1998. Water Quality in the Potomac River Basin, Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia, 1992-96: U.S. Geological Survey Circular 1166. Baltimore, MD. 38 pp.

Biggam, P. 2001. Personal Communication. Soil Scientist, NPS-Inventory and Monitoring Program. Denver, CO.

Baloch, M.S., M.N. Islam, and J.C. Burchinal. 1973. Potomac River Basin, Volume 1- Inventory. West Virginia Department of natural Resources, Division of Water Resources. Charleston, WV. 220 pp.

Belval, D.L. and L.A. Sprague. 1999. Monitoring Nutrients in the Major Rivers Draining to Chesapeake Bay. Water-Resources Investigations Report 99-4238. Richmond, VA. 14 pp.

Brakebill, J.W. 1993. Analyzing Effects of Land Use on Ground-Water Quality in the Potomac River Basin (Abstract). U.S. Geological Survey. Baltimore, MD. p.1.

Brakebill, J.W. 1994. Applications of a Geographic Information System in Water-Quality Assessment, Potomac River Basin Study Unit, National Water-Quality Assessment Program (Abstract). Abstract Booklet, Mid-Atlantic Highlands Area Environmental Monitoring and Assessment Conference. Hershey, Pennsylvania. February 23-25, 1994, p. 63.

Bricker, R. 2000. Personal Communication. NPS-Maintenance Division, Chesapeake and Ohio Canal National Historical Park.

Burke, T.A., J.S. Litt, and M.A. Fox. 1999. Linking Public Health and the Health of the Chesapeake Bay. John Hopkins School of Hygiene and Public Health, Baltimore, MD. [In} Environmental Research Section A 82:143-149.

Chesapeake Bay Foundation. 1991. Chesapeake Bay, Passageways for Migratory Fishes. Annapolis, MD. 6 pp.

Conway, B. 2000. Personal Communication. NPS-Park Ranger, Chesapeake and Ohio Canal National Historical Park. Big Spring, MD.

Copenhaver, D. Personal Communication. NPS-Engineer, Chesapeake and Ohio Canal National Historical Park.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Dept. Interior – Fish and Wildlife Service, FWS/OBS-79/31.

Dewberry & Davis. 1997. Harpers Ferry – C & O Canal Flooding Mitigation (Draft). Fairfax, Virginia. 16 pp. + appendices.

Doheny, E.J. 1997. Flood-Hydrology Data for the Potomac River and Selected Tributaries in the Vicinity of the Chesapeake and Ohio Canal National Historical Park, Maryland, West Virginia, and the District of Columbia. USGS Open-File Report 97-200. Baltimore, MD. 33 pp.

Donnelly, C.A. and M.J. Ferrari. 1998. Summary of Pesticide Data from Streams and Wells in the Potomac River Basin. U.S. Geological Survey. Baltimore, MD. 8 pp.

Ecology and Environment, Inc. 1997. Site Investigation, Chesapeake and Ohio Canal, Brunswick, Maryland. Arlington, VA. pp. 1-1 – 5-2 + appendices.

Elliott, W.D. and R.J. Montgomery. 1981. A Survey of the Macroinvertebrates of the Antietam Creek. Hagerstown Junior College. Hagerstown, MD. pp. 15.

Enamait, E.C., J.E. Mullican, L.L. Grimes. 1990. Little Pool 1986-1990. Maryland Department of Natural Resources Tidewater Administration. 9 pp. + tables & figures.

Feller, D. 1994. Aquatic Subterranean Macroinvertebrate Survey of the C&O Canal National Historic Park in Western Washington County, Maryland. Maryland Natural Heritage Program, Maryland Department of Natural Resources. Annapolis, MD. 39 pp. + appendices.

Feller, D.J. 1997. Aquatic Subterranean Macroinvertebrate Survey of the C&O Canal National Historic Park: Blue Ridge and Piedmont Physiographic Province Region. Heritage and Biodiversity Conservaion Programs, Maryland Department of Natural Resources. Annapolis, MD. 38 pp. + appendices.

Feltz, H.R. and W.J. Herb. 1977. Trends in Sedimentation. [In] The Freshwater Potoamc, Aquatic Communities and Environmental Stresses. K.C. Flynn and W.T. Mason (eds.). Proceedings of a Symposium in January 1977, College Park, MD. Interstate Commission on the Potomac River Basin, Rockville, MD. pp. 167-171.

Fisher, G.T. 1995. Selected Herbicides in Major Streams in the Potomac River Basin Upstream from Washington D.C. U.S. Geological Survey NAWQA Fact Sheet 107-95. Towson, MD. 5 pp.

Forester, D.C. 1999. Amphibian Inventory, Chesapeake & Ohio Canal and National Historic Park (Miles 0-60). Towson University, Department of Biological Sciences. Towson, MD. pp. 2 – 11.

Fry, J.F. and J. Meiman. 1994. The Development of a Karst Groundwater Hazardous Spill Map within the Drainage Basins of Mammoth Cave. Mammoth Cave National Park, Mammoth Cave, KY. 10 pp.

Gerhart, J. M. and J, D. Blomquist. 1992. Selected Trace-element and Organic Contaminants in Streambed Sediments of the Potomac River Basin. U.S. Geological Survey, Water Resources Investigation Report 95-4267. Towson, Maryland.

Goldfarb, W. 1988. Water Law, 2nd Ed.: Lewis Publishers, Inc. Chelsea, MI. 284 pp.

Hitt, K.J. 1994. Refining 1970's land-use data with 1990 population data to indicate new residential development: U.S. Geological Survey Water-Resources Investigations Report 94-4250. 15 pp.

Hobba, W.A., Jr., E.A. Friel, and J.L Chisholm. 1972. Water Resources of the Potomac River Basin, West Virginia. River Basin Bulletin 3. U.S. Geological Survey, Water Resources Division. 110 pp.

Hogan, K.B., R.C. Steiner, B.A. Spielmann, and D.P. Sheer. 1986. A Toxic Spill Model for the Potomac River Basin. Report No. 86-1. Interstate Commission on the Potomac River Basin. Rockville, Maryland. 49 pp.

Ingram, D. 2000. Personal Communication. Natural Resource Management Specialist, Chesapeake and Ohio Canal National Historical Park. Big Spring, MD.

Ingram, D. 2000. Personal Communication. Natural Resource Management Specialist, Chesapeake and Ohio Canal National Historical Park. Big Spring, MD.

Interstate Commission on the Potomac River Basin. 1976. Legal Rights in Potomac Waters. Proceedings of a Conference at Harper's Ferry, West Virginia. G. Power (ed.). ICPBR General Publication 76-2. Bethesda, Maryland. 213 pp. + appendices

Jenkins, R. and N. Burkherd. 1993. Freshwater Fishes of Virginia. Amer. Fisheries Society. Bethesda, MD. pp. 65-67

Karr, J.R., and I.J. Schlosser. 1978. Water Resources and the Land-Water Interface. Science 201:229-234.

Laughlin, C.P. and E. G. Otton. 1964. Preliminary Report on Ground-Water Conditions Along the C & O Canal, Maryland. U.S. Geological Survey. Washington, D.C. 16 pp.

Leopold. L.B. 1997. Water, Rivers and Creeks. University Science Books. Sausalito, CA. 185 pp.

Lowrance, R., R. Leonard, and J. Sheridan. 1985. Managing Riparian Ecosystems to Control Nonpoint Pollution. Jour. Soils and Water Cons. 40:87-91.

Lowrance, R., L.S. Altier, J.D. Newbold, R.R. Schnabel, P.M. Groffman, J.M. Denver, D.L. Correll, J.W. Gilliam, J.L. Robinson, R.B. Brinsfield, K.W. Staver, W. Lucas, and A.H. Todd. 1995. Water Quality Functions of Riparian Forest Buffer Systems in Chesapeake Bay Watershed. Nutrient Subcommittee of the Chesapeake Bay Program. EPA 903-R-95-004. 67 pp.

MacIvor, L., K. Motivans, V. Tierce, C. Baer, D. Nash, and K. Boyle. 1995. Freshwater Mussel Surveys of the C&O Canal National Historical Park and Potomac River in Washington, Frederick, and Montgomery Counties in Maryland. Maryland Natural Heritage Program, Maryland Department of Natural Resources. Annapolis, MD. 74 pp. + appendices.

Maryland Department of Natural Resources. 1981. Potomac River Environmental Flow-By Study. Annapolis, Maryland. 130 pp. + appendices.

Maryland Department of Natural Resources. 1999. New Survey Takes Maryland Streams into the Next Millennium. Nonpoint Source News-Notes, November 1999, Issue #59. Annapolis, MD. pp. 14-16.

Naiman, R.J. and H. Décamps. 1997. The Ecology of Interfaces; Riparian Zones. University of Washington, School of fisheries, Seattle, Washington, Annu. Rev. Ecol. Syst. 1997. 28:621-58.

National Climate Data Center. 2000. NCDC TD 9641 Clim 81 1961-1990 Normals. <URL:http//www.worldclimate.com/cgi-bin/data.pl?ref=N38W077+1300+ 4489006C, 1302+448906C, 1304+448906C, 2300+448906C> <URL:http//www. worldclimate.com/cgi-bin/data.pl?ref=N39W078+1300+ 182282C, 1302+ 182282C, 1304+182282C, 2300+182282C> <URL:http//www.worldclimate.com/ cgi-bin/data.pl?ref=N39W077+1300+183975C, 1302+183975C, 1304+183975C, 2300+183975C>.

National Park Service. 1978. Information Base, Chesapeake and Ohio Canal National Historical Park, Great Falls, Maryland. NPS – Denver Service Center. Denver, CO. 142 pp.

National Park Service. 1995. The Potomac River Watershed: A National Resource. An Assessment of Significant Natural, Cultural, and Recreational Resources (Draft). NPS - Mid-Atlantic Regional Office, Division of Park and Resource Planning. Philadelphia, PA. 51 pp.

National Park Service. 1996a. Resources Management Plan, Chesapeake and Ohio Canal National Historic Park. Sharpsburg, MD. pp. 1.0-1.9, 2.0-2.31, 3.0-3.19 + appendices.

National Park Service. 1996b. Baseline Water Quality Data Inventory and Analysis, Chesapeake and Ohio Canal National Historical Park (Volumes 1, II, III & IV). Technical Report NPS/NRWRD/NRTR-96-87. National Park Service, Water Resources Division. Ft. Collins, CO.

National Park Service. 1997. Flood Recovery Plan, Chesapeake and Ohio Canal National Historical Park. Sharpsburg, MD. 39 pp. + appendices.

National Park Service. 1998a. National Park Service Procedural Manual 77-1: Wetland Protection, Technical Report NPS/NRWRD/NRTR/-98-203. NPS, Water Resources Division. Ft. Collins, CO. 32 pp.

National Park Service. 1998b. The National Park Service Chesapeake Bay Riparian Buffer Plan. NPS-Northeast Region. Philadelphia, PA. 39 pp.

National Park Service, 1999. National Capital Region Natural Resources Information Status Report. Lands, Resources, and Planning, Natural Resource and Science Services, and Natural Resources Advisory Team. Washington D.C.

National Park Service. 2000a. National Park Service, Management Policies (Draft). Washington D.C. Ch. 4.

National Park Service. 2000b. Follow-up on Serious HazMat Spill (00-216) – Rock Creek Park (DC). NPS Electronic Bulletin Board, Ranger Report (May 30, 2000).

Nutter, L.J. 1974. Well yields in the bedrock aquifers of Maryland. Maryland Geologic Survey, Information Circular 16. 24 pp.

Otten E.G. and J.T. Hilleary. 1985. Maryland springs – Their physical, thermal, and chemical characteristics. Maryland Geological Survey, Report of Investigations 42. 151 pp.

Poulson, T.L. and T.C. Kane. 1977. Ecological Diversity and Stability: Principles and Management. [In] National Cave Management Symposium Proceedings. T. Aley and D. Rhodes (eds.). October 26-29, 1976. Speleobooks, Albuquerque, NM.

Reed, W.B., S.S. Schwartz, and R.S. Hammerschlag. 1990. ELARC: Hydrologic Forecasting for Floodplain Management within the Potomac River Basin – Phase 1. Technical Report NPS/NRWRD/NRTR-90/04. National Park Service, Water Resources Division. Ft. Collins, CO. 9 pp.

Rosenlieb, G. and B. Zander. 2000. Use of Clean Water Act 303d Impaired Water Lists for Reporting to NPS Strategic Plan Goal 1a4 (draft). National Park Service, Water Resources Division. Ft. Collins, CO.

Roth, N.E., J. Chaillou, and M. Gaughan.1997. Guide to using 1995 Maryland Biological Stream Survey Data. Prepared for Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division, by Versar, Inc., Columbia, MD.

Roth, N.E., M.T. Southerland, J.C. Chaillou, J.H. Volstad, S.B. Weisber, H.T. Wilson, D. G. Heimbuch, and J. C. Seibel. 1997. Maryland Biological Stream Survey: Ecological Status of Non-Tidal Streams in Six Basins Sampled in 1995.Prepared by Versar, Inc., Columbia, MD, and Coastal Environmental Series, Linthicum, MD, for Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division, Annapolis, MD.

Sauter, R. 2000. Personal Communication. Park Ranger, Chesapeake and Ohio Canal National Historical Park. Sharpsburg, MD.

Seavolt, R. 1999. Status Report of Dwarf Wedge Mussel (Alasmidonta heterodon). 12 pp. + attachments.

Secor, T.H. 1977. Controlling Sediment Damage. [In] The Freshwater Potoamc, Aquatic Communities and Environmental Stresses. K.C. Flynn and W.T. Mason (eds.). Proceedings of a Symposium in January 1977, College Park, MD. Interstate Commission on the Potomac River Basin, Rockville, MD. pp. 174-178.

Shaffer, D.R. 1997. “We are again in the Midst of Trouble”: Flooding of the Potomac River and the Struggle for the Sustainability of the Chesapeake and Ohio Canal, 1928-1996. Scope of Work #11. University of Maryland, College Park, MD. 129 pp.

Stitt, RR. 1977. Human Impact on Caves. . [In] National Cave Management Symposium Proceedings. T. Aley and D. Rhodes (eds.). October 26-29, 1976. Speleobooks, Albuquerque, NM.

Smillie, G.M. and D. Curtis. 1996. Trip Report for Travel to Chesapeake and Ohio Canal National Historic Park, February 6 – 9, 1996. Ft. Collins, CO. 5 pp.

Southworth, S., D.K. Brezinski, R.C. Orndorff, and P. Chirico. 2000. (Draft) Geology of the Chesapeake and Ohio Canal National Historical Park and Potomac River Corridor, District of Columbia, Maryland, West Virginia, and Virginia.

Starnes, W.C. 1999. Current Diversity, Historical Analysis, and Biotic Integrity of Fishes in the Lower Potomac Drainage in the Vicinity of Plummers Island, Maryland (Draft I). Washington Biologists Field Club, HMNH MRC 180, Washington, D.C. 26 pp. + tables.

Thompson, E. 2000. An Amphibian Survey of the C&O Canal National Historical Park in Allegany and Washington Counties, Maryland. Maryland Department of Natural Resources, Wildlife and Heritage Division. Annapolis, MD. pp. 60.

Thomson, D., A.M.A. Gould, and M.A. Berdine. 1999. Identification and Protection of Reference Wetland Natural Communities in Maryland: Potomac Watershed Floodplain Forests. The Biodiversity Program, Maryland Department of Natural Resources Wildlife and Heritage Division. Annapolis, MD. pp.119.

Trainer, F.W., and F.A. Watkins, Jr. 1975. Geohydrologic Reconnaissance of the Upper Potomac River Basin. Geological Survey Water-Supply Paper 2035. Washington D.C. 68 pp.

U.S. Fish and Wildlife Service. 2000. April 24, 2000 letter re: Dam 4 and 5 Hydro Stations Projects, (FERC No. 2516 & 2517), Potomac River, in the counties of Washington, Maryland and Moran and Berkeley, West Virginia. Annapolis, MD. 7 pp.

U.S. Geological Survey. 1994. River Basins of the United States: The Potomac. Denver, CO. 9 pp.

U.S. Geological Survey. 2000. Historical Streamflow Daily Values Graph for Potomac River. http://sunweb1.er.usgs.gov/rt-cgi/gen_map_pg?map=potomac_lower and potomac_upper.

West Virginia Department of Natural Resources. 1981. Potomac River Basin, Volume III. Problems, Resource Base, Projections, Needs and Alternative Plans. Charleston, WV. 368 pp.

William & Mary. 2000. The Geology of Virginia. The College of William and Mary, Williamsburg, Virginia. <URL:http//www.wm.edu/cas/geology/ virginia/ coastal_plain.html, piedmont.html, blue_ridge.html, valley_ridge.html, coastal_plain.html>

Yanosky, T.M. 1982. Effects of Flooding Upon Woody Vegetation along Parts of the Potomac River Flood Plain. U.S. Geological Survey Professional Paper 1206. Alexandria, VA. 21 pp.

Yetman, K. 2001. Personal Communication. Maryland Stream Corridor Assessment Survey. Maryland Department of Natural Resources, Watershed Restoration Division (410.260.8812). Annapolis, MD.

Appendix A. U.S. Geological Survey streamflow-gaging stations with surface-water flowdata in the vicinity of the Chesapeake and Ohio Canal National Historical Park (Doheny, 1997).

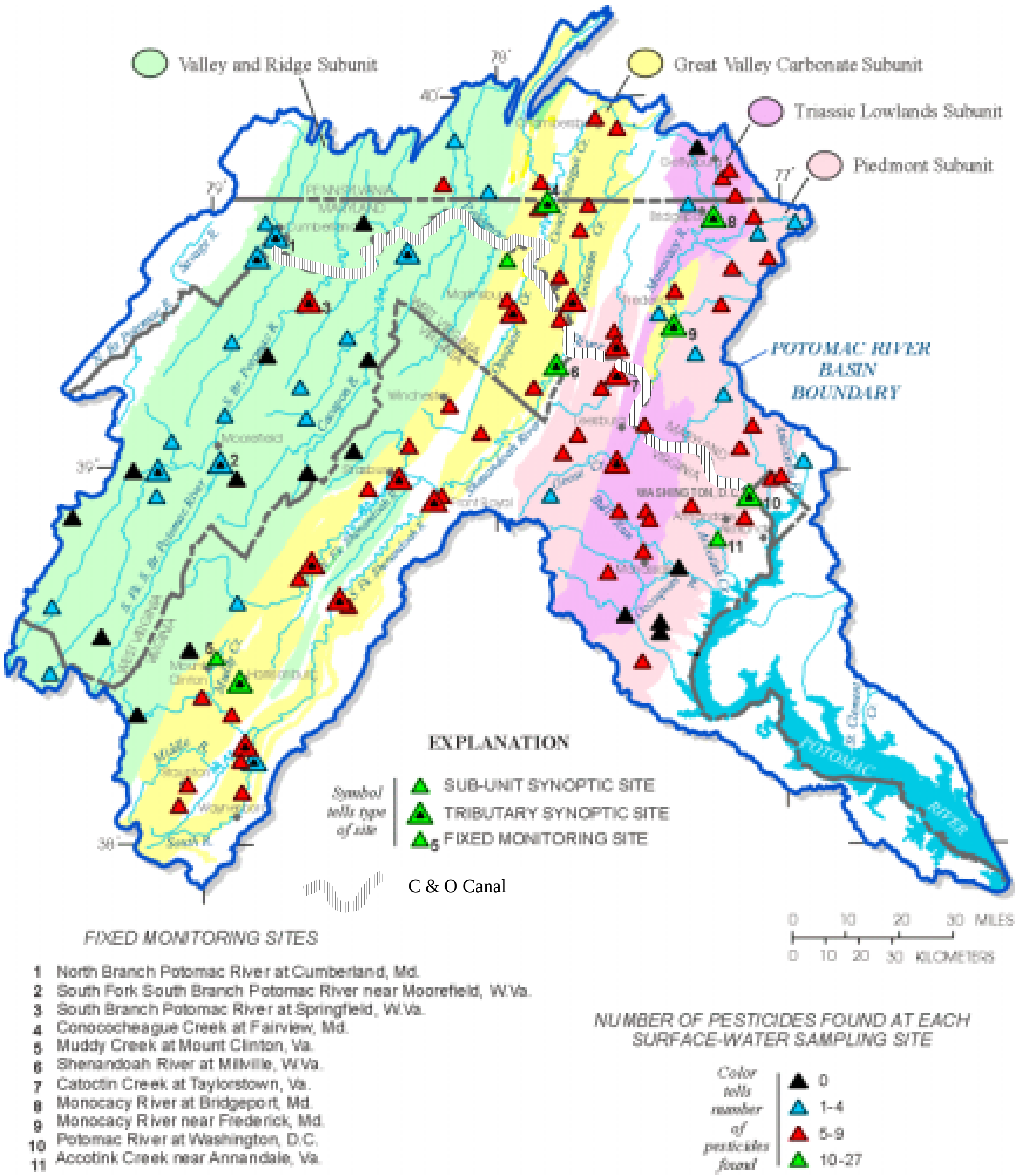
Station no.	Station name and location	Period of record	Data type
01601500	Wills Creek near Cumberland, Md.	1929-present	discharge, other
01602000	Chesapeake and Ohio Canal at Cumberland, Md.	1929-34	discharge
01603000	North Branch Potomac River near Cumberland, Md.	1929-present	discharge
01604000	Evitts Creek near Cumberland, Md.	1929-32	discharge, other
01604150	Collier Run at Spring Gap, Md.	1964-74	low flow
01605425	Mill Run at Oldtown, Md.	1975-77	low flow
01605475	Seven Springs Run at Oldtown, Md.	1975-81	low flow
01605600	Friends Run near Franklin, W. Va.	1969-77	discharge
01606000	North Fork South Branch Potomac River at Cabins, W. Va.	1940-61	discharge
01607000	Big Spring at Masonville, W. Va.	1946-59	discharge
01608050	Fort Run near Moorefield, W. Va.	1969-77	discharge
01608400	Buffalo Creek near Romney, W. Va.	1969-77	discharge
01608500	South Branch Potomac River near Springfield, W. Va. 1	1928-present	discharge, other
01608975	Maple Run near Town Creek, Md.	1977-78, 80-81	low flow
01609000	Town Creek near Oldtown, Md.	1928-35, 67-81	discharge, other
01609500	Sawpit Run near Oldtown, Md.	1948-58	discharge, other
01609800	Little Cacapon River near Levels, W. Va.	1966-77	discharge
01610000	Potomac River at Paw Paw, W. Va.	1938-present	discharge
01610030	Potomac River at Magnolia, W. Va.	1958-67	high flow
01610065	Deep Run near Little Orleans, Md.	1975-77	low flow
01610075	Fifteen Mile Creek at Little Orleans, Md.	1975-79	low flow
01610155	Sideling Hill Creek near Bellegrove, Md.	1967-77	discharge, other
01610170	Potomac River tributary at Woodmont, Md.	1985-86	low flow
01610200	Lost River at McCauley near Baker, W. Va.	1972-80	discharge
01610300	Cacapon River above Wardensville, W. Va.	1972-73	discharge
01610500	Cacapon River at Yellow Spring, W. Va.	1940-52	discharge
01611200	North River at North River Mills, W. Va.	1960-64, 69-70	low flow
01611500	Cacapon River near Great Cacapon, W. Va.	1922-95	discharge
01612500	Little Tonoloway Creek near Hancock, Md.	1947-63	discharge, other
01613000	Potomac River at Hancock, Md.	1932-present	discharge, other
01613100	Tonoloway Creek at Hancock, Md.	1985-86	low flow
01613150	Ditch Run near Hancock, Md.	1965-86	high flow, low flow
01613160	Potomac River tributary near Hancock, Md.	1965-76	high flow
01613400	Sleepy Creek near Berkeley Springs, W. Va.	1960-64, 70	low flow
01613545	Licking Creek near Pectonville, Md.	1985-86	low flow

Station no.	Station name and location	Period of record	Data type
01614000	Back Creek near Jones Springs, W. Va.	1928-74	discharge
01614050	Little Conococheague Creek near Charlton, Md.	1985-86	low flow
01614500	Conococheague Creek at Fairview, Md.	1928-present	discharge
01614625	Meadow Brook at Conococheague, Md.	1976-79, 81-82, 85-86	low flow
01614705	Conococheague Creek at Williamsport, Md.	1985-86	low flow
01614850	Potomac River near Falling Waters, W. Va.	1958-67	high flow
01616500	Opequon Creek near Martinsburg, W. Va. 1	1947-present	discharge
01617000	Tuscarora Creek above Martinsburg, W. Va.	1949-63, 68-77	discharge
01617600	Downey Branch near Downsville, Md.	1976-79, 81	low flow
01617780	St. James Run at Spielman, Md.	1977-79, 81-82, 85-86	low flow
01617800	Marsh Run at Grimes Md.	1963-present	discharge
01617850	Potomac River at Lock 40 near Mondell, Md.	1957-67	high flow
01618000	Potomac River at Shepherdstown, Md.	1928-93	discharge, high flow
01619500	Antietam Creek near Sharpsburg, Md.1	1928-present	discharge, other
01619525	Sharmans Branch near Antietam, Md.	1977-79, 81	low flow
01620000	Chesapeake and Ohio Canal at Point of Rocks, Md.	1931-36	discharge
01636500	Shenandoah River at Millville, W. Va.1	1928-present	discharge
01636650	Potomac River at Weverton, Md.	1958-70	high flow
01636690	Piney Run near Lovettsville, Va.	1968-69	low flow
01636730	Israel Creek at Weverton, Md.	1975-77	low flow
01636850	Little Catoctin Creek near Brunswick, Md.	1977-81	low flow
01638480	Catoctin Creek at Taylorstown, Va.	1971-present	discharge
01638500	Potomac River at Point of Rocks, Md.	1895-present	discharge
01638600	Tuscarora Creek at Tuscarora, Md.	1975-77	low flow
01643000	Monocacy River near Frederick, Md.	1929-present	discharge
01643495	Bennett Creek tributary at Park Mills, Md.	1992-93	discharge
01643500	Bennett Creek at Park Mills, Md. 1	1966-present	discharge
01643550	Potomac River at Lock 27 near Dickerson, Md.	1957-68	high flow
01643580	Monocacy River near Dickerson, Md.	1975-77, 79-83	misc. meas.
01643585	Potomac River tributary near Lucketts, Va.	1979-80	low flow
01643590	Limestone Branch near Leesburg, Va.	1968-69	misc. meas.
01643600	Limestone Branch tributary near Leesburg, Va.	1979-80	low flow
01643615	Broad Run near Elmer, Md.	1975-82	low flow
01644000	Goose Creek near Leesburg, Va. 1	1930-present	discharge
01644100	South Fork-Sycolin Creek near Leesburg, Va.	1966-77	high flow
01644115	Dry Mill Branch near Leesburg, Va.	1969	misc. meas.
01644277	Beaverdam Run near Ashburn, Va.	1979-81	misc. meas.
01644283	Potomac River tributary No. 2 near Sterling, Va.	1979-80	misc. meas.
01645000	Seneca Creek at Dawsonville, Md.	1930-present	discharge
01645050	Dry Seneca Creek near Seneca, Md.	1975-82	low flow

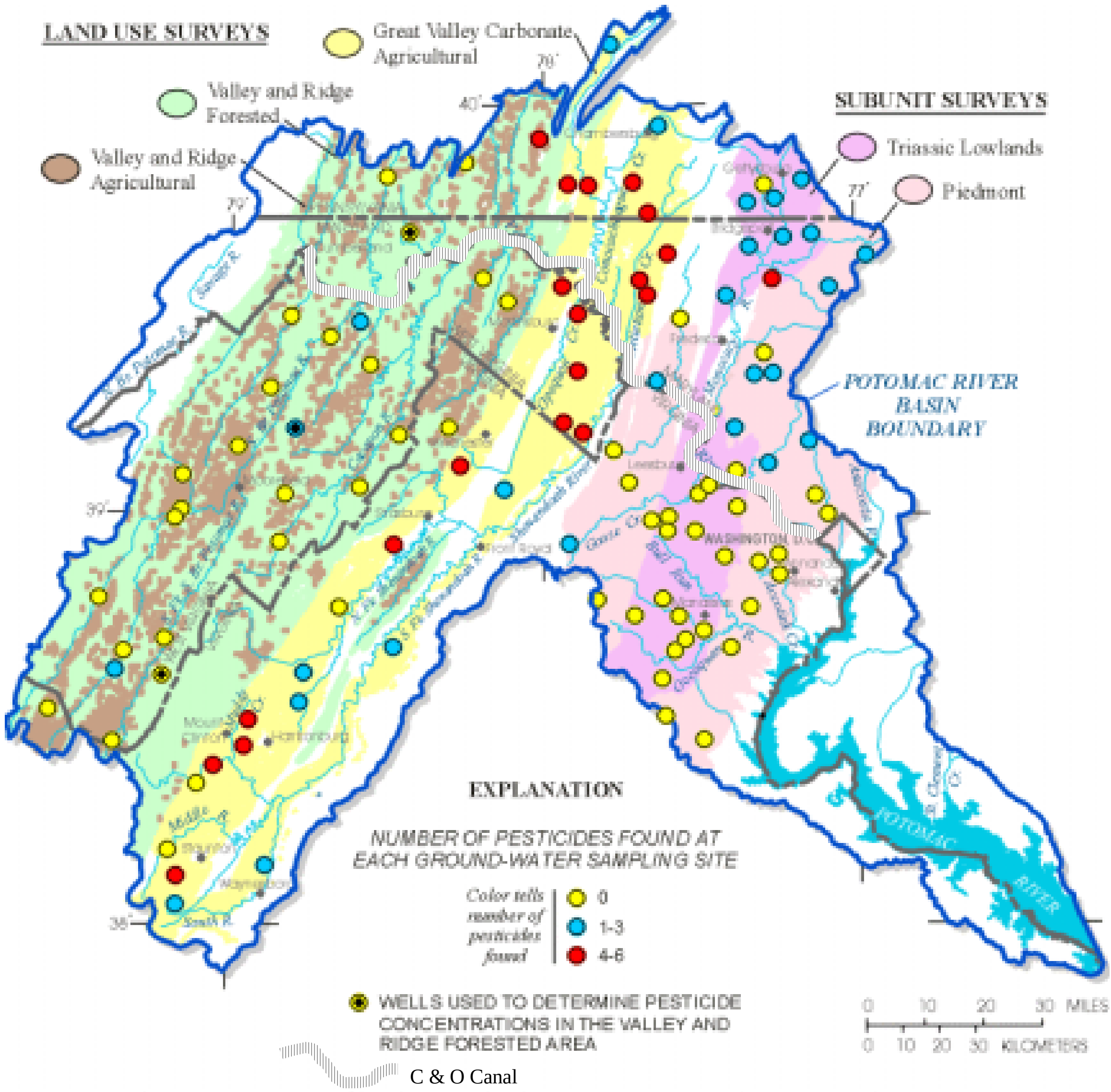
Station no.	Station name and location	Period of record	Data type
01645080	Seneca Creek near Seneca, Md.	unknown	misc. meas.
01645500	Potomac River at Great Falls, Md.	1886-1891	discharge
01645975	Rocky Run near Great Falls, Va..	1961-67	high flow
01646000	Difficult Run near Great Falls, Va.	1934-present	discharge
01646200	Scott Run near McLean, Va.	1961-73	high flow
01646220	Rock Run near Cabin John, Md.	1964, 66-67	low flow
01646500	Potomac River near Washington, D.C.	1930-present	discharge
01646550	Little Falls Branch near Bethesda, Md.	1944-59, 62-79	discharge
01646700	Pimmitt Run at Arlington, Va.	1961-68	high flow
01646750	Little Pimmitt Run tributaryat Arlington, Va.	1962-66	high flow
01646755	Little Pimmitt Run tributary at Arlington, Va.	1962-69	high flow
01646800	Little Pimmitt Run at Arlington, Va.	1961-66	high flow
01647600	Potomac River at Wisconsin Avenue at Washington, D.C.	1935-present	tide gage
01648000	Rock Creek at Washington, D.C.	1929-present	discharge
01649000	Rock Creek at Q Street at Washington, D.C.	1892-1895, 1930-1933	discharge
01652580	Oxen Run at Washington, D.C.	1980-82	low flow

1 Station contains other shorter periods of record prior to current period of record.
[misc. meas. = miscellaneous measurement]

Appendix B. Location of surface water sampling sites within the Potomac River Basin and the number of pesticides detected at each site, 1993-1995 (modified after Donnelly and Ferrari, 1998).



Appendix C. Location of ground water sampling sites within the Potomac River Basin and the number of pesticides detected at each site, 1993-1995 (modified after Donnelly and Ferrari, 1998).



Appendix D. Chesapeake and Ohio Canal National Historical Park, Listed Species.

Crustaceans	**Common Name**	**Global Rank**	**Federal Status**	**State Rank/ Status**
Ankylocythere tridentata	An Entocytherid Ostracod	G?		MD:SX
Caecidotea pricei	Price's Cave Isopod	G3		MD:S3
Caecidotea SP2	An Isopod	G?		MD:S1
Caecidotea SP3	An Isopod	G3		MD:S1
Caecidotea SP4	An Isopod	G?		MD:S1
Eulimnadia francesae	A Clam Shrimp	G?		MD:SU
Eulimnadia ventricosa	A Clam Shrimp	G?		MD:SU
Stygobromus allegheniensis	Allegheny Cave Amphipod	G4		MD:S2S3/1
Stygobromus biggersi	Biggers Cave Amphipod	G1G2	C2	MD:S1/E
Stygobromus franzi	Franz's Cave Amphipod	G2		MD:S2/S3/I
Stygobromus gracilipes	Shenandoah Cave Amphipod	G2		MD: S1/E
Stygobromus pizzinii	Pizzini's Cave Amphipod	G2		MD:S1
Stygobromus tenuis Potomacus	Potomac Amphipod	G4T3Q		MD:S3
Mollusks				
Alasmidonta heterodon	Dwarf Wedge Mussel	G1	LE	DC:SH
Alasmidonta varicosa	Brook Floater	G3		MD:S1/E
Elliptio producta	Atlantic Spike	G4Q		MD:S2S3
Fontigens orolibas	Blue Ridge Spring Snail	G3		MD:S1/E
Hendersonia occulta	Cherrydrop Snail	G4		MD:S2/1
Lampsilis cariosa	Yellow Lampmussel	G4		MD:S1/X
Lampsilis radiata	Eastern Lampmussel	G5		MD:SU
Lasmigona subviridis	Green Floater	G3	C2	MD:S1/E
Strophitus undulatus	Squawfoot	G5		MD:S2S3
Reptiles				
Farancia erytrogramma	Rainbow Snake	G5		MD:S1/E
Fishes				
Percopsis omiscomaycus	Trout-Perch	G5		MD:SH/X
Birds				
Actitis macularia	Spotted Sandpiper	G5		DC:S4N,SPB
Ammondramus henslow	Henslow's Sparrow	G4		MD:S1B/T
Dendroica cerulea	Cerulean Warbler	G4		DC:S2N,SPB
Dendroica dominica	Yellow-throated Warbler	G5		DC:S1N,SPB
Haliaeetus leucocephalus	Bald Eagle	G4	LT	MD:S2S3B/E
Vireo gilvus	Warbling Vireo	G5		DC:S1B,S1S2N
Mammals				
Myotis leib	Eastern Small-Footed Bat	G3		MD:S1B/I
Myotis sodalis	Indiana Bat	G2	LE	MD:S1B?/E
Neotoma magister	Allegheny Woodrat	G3G4	C2	MD:S1E
Vascular Plants – Ferns and Allies				
Asplenium resiliens	Black-Stem Spleenwort	G5		MD:S1/E
Azolla caroliniana	Mosquito Fern	G5		MD:S1
Diplazium pycnocarpon	Glade Fern	G5		MD:S1/T
Equisetum arvense	Field Horsetail	G5		DC:S3
Matteuccia struthiopteris	Ostrich Fern	G5		MD:S2
Pellaea glabella	Smooth Cliffbrake	G5		MD:S1/E

Vascular Plants – Gynmosperms	Common Name	Global Rank	Federal Status	State Rank/ Status
Thuja occidentalis	Arbor-Vitae	G5		MD:S1/T

Vascular Plants – Monocots

Arisaema dragontium	Green Dragon	G5		DC:S1S3
Aristida curtissii	Curtiss' Three-Awn	G5T5		MD:SU
Aristida lanosa	Woolly Three-Awn	G5		MD:S1/E
Bouteloua curtipendula	Side-Oats Grama	G5		MD:S2
Bromus hordeaceus	Soft Chess	G?		MD:S2
Bromus latiglumis	Broad-Glumed Bromegrass	G5		DC:SX
Bromus nottowayanus	Nottoway's Brome	G3G4		MD:SH/X
Carex aggregata	Glomerate Sedge	G5		MD:SH/X
Carex careyana	Carey's Sedge	G5		MD:SH/X
Carex conjuncta	Soft Fox Sedge	G4G5		MD:SH/X
Carex davisii	Davis' Sedge	G4		MD:SH/X
Carex decomposita	Cypress-Knee Sedge	G4		MD:SH/X
Carex gray	Asa Gray's Sedge	G4		DC:S1?
Carex hirtifolia	Pubescent Sedge	G5		MD:S1/E
Carex hitchcockiana	Hitchcock's Sedge	G5		MD:S1/E
Carex jamesii	James' Sedge	G5		DC:S1
Carex lanuginosa	Woolly Sedge	G5		MD:S2/T
Carex leavenworthii	Leavenworth's Sedge	G5		MD:SH/X
Carex louisianica	Louisiana Sedge	G5		DC:S1
Carex shortiana	Short's Sedge	G5		DC:S1
Carex tenera	Slender Sedge	G5		MD:SH
Carex tetanica	Rigid Sedge	G4G5		MD:SH/X
Carex woodii	Wood's Sedge	G4Q		MD:SH/X
Cinna latifolia	Slender Wood Reedgrass	G5		MD:S2/T
Corallorrhiza wisteriana	Wister's Coralroot	G5		DC:SX
Cyperus lancastriensis	Lancaster's Umbrella Sedge	G5		DC:S1S3
Cyperus retrofractus	Rough Cyperus	G5		MD:S2
Cyperus squarrosus	Awned Umbrella Sedge	G5		DC:S1
Diarrhena americana	Twin Oats	G3G5		MD:S1/E
Echinodorus cordifolius	Heart-Leaved Burhead	G5		DC:SX
Eleocharis compressa	Flattened Spikerush	G4		DC:S1
Erythronium albidum	White Trout Lily	G5		DC:S2
Iris cristata	Crested Iris	G5		MD:S1/E
Iris versicolor	Blue Flag	G5		DC:S1
Lemna trisulca	Star Duckweed	G5		MD:S1/E
Lipocarpha micrantha	Small-Flowered Dwarf Bulrush	G4		DC:S1
Melanthium latifolium	Broad-Leafed Bunchflower	G5		MD:SH/X
Melica mutica	Narrow Melicgrass	G5		MD:S1/T
Melica nitens	Three-Flowered Melicgrass	G5		MD:S2/T
Muhlenbergia capillaris	Long-Awned Hairgrass	G5		MD:S1/E
Najas gracillima	Thread-Like Naiad	G5?		MD:SH/X
Oryzopsis racemosa	Black-Fruited Mountainrice	G5		MD:S2/T
Panicum laxiflorum	Lax-Flowered Witchgrass	G5		MD:SU
Panicum oligosanthes	Few-Flowered Panicgrass	G5		MD:S1/E
Paspalum fluitans	Floating Paspalum	G5		MD:S1/E
Platanthera peramoena	Purple Fringeless Orchid	G5		DC:SX
Potamogeton foliosus	Leafy Pondweed	G5		MD:S1/E
Potamogeton foliosus var foliosus	Leafy Pondweed	G5		DC:SX
Potamogeton zosteriformis	Flatstem Pondweed	G5		MD:SH/X
Rhynchospora glomerata	Clustered Breakrush	G5		MD:S2/E
Sagittaria engelmanniana	Engelmann's Arrowhead	G5?		MD:S2/T
Sagittaria longirostra	Long-Beaked Arrowhead	G?		MD:SU
Sagittaria rigida	Sessile-Fruited Arrowhead	G5		DC:SX
Sisyrinchium montanum	Pointed Blue-Eyed Grass	G5		DC:S1
Smilacina stellata	Star-Flowered False Solomon's Seal	G5		MD:S1/E
Spartina pectinata	Prairie Cordgrass	G5		DC:S1
Spiranthes lucida	Wide-Leaved Ladies' Tresses	G5		DC:SX
Sporobolus asper	Long-Leaved Rushgrass	G5		MD:S1
Sporobolus clandestinus	Rough Rushgrass	G5		MD:S1
Trillium nivale	Snow Trillium	G4		MD:S1/E

Vascular Plants – Monocots (cont.)	Common Name	Global Rank	Federal Status	State Rank/ Status
Trillium sessile	Sessile Trillium	G4G5		DC:S1
Triphora trianthophora	Nodding Pogonia	G4		MD:SH/X

Vascular Plants – Dicots

Agalinis auriculata	Auricled Gerardia	G3		MD:S1/E
Agrimonia microcarpa	Small-Fruited Agrimony	G5		MD:S1/E
Amelanchier spicata	Running Juneberry	G5		MD:S1/T
Ammannia coccinea	Scarlet Ammannia	G5		DC:S1
Apocynum sibiricum	Clasping-Leaved Dogbane	G5?		MD:SH/X
Arabis hirsuta	Hairy Rockcress	G5		MD:SU
Arabis missouriensis	Missouri Rockcress	G4?Q		MD:S1/E
Arabis shortii	Short's Rock Cress	G5		DC:SH
Armoracia lacustris	Lake Cress	G4?	3C	MD:S1/E
Arnica acaulis	Leopard's Bane	G5		MD:S1/E
Arnoglossum muehlenberg	Great Indian Plantain	G4		DC:SX
Aster concinnus	Steele's Aster	G5T4		MD:SH/X
Aster depauperatus	Serpentine Aster	G2Q	C2	MD:S1/E
Aster drummond	Drummond Aster	G5Q		MD:S1
Astragalus canadensis	Canada Milkvetch	G5		DC:SX
Astragalus distortus	Bent Milkvetch	G5		MD:S2/T
Baptisia australis	False Blue Indigo	G5		DC:S1
Bidens discoidea	Swamp Beggar Ticks	G5		MD:S2S3
Calystegia spithamaea	Low Bindweed	G4G5		MD:S2
Campanula rotundifolia	Harebell	G5		MD:S2
Cardamine pratensis	Cuckooflower	G5		MD:S1
Carya laciniosa	Big Shellbark Hickory	G5		MD:S1/E
Caulophyllum thalictroides	Blue Cohosh	G5		DC:S1
Ceanothus herbaceus	Prairie Redroot	G5		DC:S1
Celtis laevigata	Sugarberry	G5		MD:SU
Cerastium arvense	Field Chickweed	G5		DC:S1
Ceratophyllum muricatum	Prickly Hornwort	G4G5		MD:S1/E
Chamaesyce vermiculata	Hairy Spurge	G5		MD:SU
Clematis viorna	Leatherflower	G5		DC:S1
Coreopsis tripteris	Tall Tickseed	G5		MD:S1/E
Cornus amomum ssp obliqua	Silky Dogwood	G5T?		DC:SU
Cuscuta cephalanthi	Buttonbush Dodder	G5		DC:SX
Cuscuta coryli	Hazel Dodder	G5		MD:SH/X
Cuscuta polygonorum	Smartweed Dodder	G5		MD:S1/E
Desmodium rigidum	Rigid Tick-Trefoil	G?Q		MD:S1/E
Dirca palustris	Leatherwood	G4		DC:SX
Echinocystis lobata	Wild Cucumber	G5		DC:SX
Ellisia nyctelea	Nyctelea	G5		DC:SX
Erigenia bulbosa	Harbinger of Spring	G5		DC:SX
Euphorbia obtusata	Blunt-Leaved Spurge	G5		MD:S1/E
Floerkea proserpinacoides	False Mermaid-Weed	G5		DC:S1
Galactia volubilis	Downy Milk Pea	G5		MD:S1/E
Galium boreale	Northern Bedstraw	G5		MD:S1/E
Galium concinnum	Shining Bedstraw	G5		DC:S5
Gentiana villosa	Striped Gentian	G4		MD:S1/E
Geum aleppicum	Yellow Avens	G5		MD:S1/E
Helianthus occidentalis	McDowell's Sunflower	G5		MD:S1/T
Houstonia tenuifola	Slender-Leaved Bluets	G4G5Q		MD:S1
Hydrastis canadensis	Goldenseal	G4		MD:S1/T
Hydrophyllum canadense	Canada Waterleaf	G5		DC:S3
Hydrophyllum macrophyllum	Large-Leaved Waterleaf	G5		MD:S1/E
Hypericum kalmianum	Kalm's St. John's Wort	G4		DC:SX
Hypericum prolificum	Shrubby St. John's Wort	G5		DC:S2
Ilex decidua	Deciduous Holly	G5		MD:S1/T
Iresine rhizomatosa	Bloodleaf	G5		MD:SH/X
Juglans cinerea	Butternut	G4		DC:S1
Krigia dandelion	Potato Dandelion	G5		DC:SX
Lactuca hirsuta	Hairy Lettuce	G4?		MD:SH/X
Lathyrus palustris	Vetchling	G5		MD:S1/X

Vascular Plants – Dicots (cont.)	Common Name	Global Rank	Federal Status	State Rank/ Status
Lathyrus venosus	Veiny Pea	G5		DC:S1
Lespedeza violacea	Violet Bushclover	G5		DC:S1
Lithospermum latifolium	American Cromwell	G5		MD:S1/E
Lysimachia hybrida	Lowland Loosestrife	G5	3C	MD:S1/E
Lythrum alatum	Winged Loosestrife	G5		DC:S1
Matelea obliqua	Climbing Milkweed	G4?		DC:SX
Mecardonia acuminata	Purple Water-Hyssop	G5		DC:SX
Melothria pendula	Creeping Cucumber	G4		DC:S1
Myosotis verna	Spring Forget-Me-Not	G5		DC:S1
Onosmodium virginianum	Virginia False-Gromwell	G4		MD:S1/E
Paronychia virginica var virginica	Virginia Nailwort	G4T1T2Q		DC:SX
Phacelia covillei	Coville's Phacelia	G2?Q		DC:S2
Phacelia pursh	Miami-Mist	G5		DC:S1
Phacelia ranunculacea	Coville's Phacelia	G2?Q		DC:S2
Polygala polygama	Racemed Milkwort	G5		MD:S1/T
Polygonum amphibium var stipulaceum	Water Smartweed	G5T?		DC:S1
Potentilla arguta	Tall Cinquefoil	G5		MD:SU
Prunus pumila	Eastern Dwarf Cherry	G5		MD:SU
Ptilimnium nodosum	Harperella	G2	LE	MD:S1/E
Pycnanthemum clinopodioides	Basil Mountain-Mint	G2		DC:SX
Pycnanthemum torre	Torrye's Mountain-Mint	G2		DC:SX
Pycnanthemum verticillatum	Whorled Mountain-Mint	G5		MD:S1/E
Pycnanthemum virginianum	Virginia Mountain-Mint	G5		MD:S2
Quercus imbricaria	Shingle Oak	G5		DC:S1S3
Quercus macrocarpa	Bur Oak	G5		DC:S1
Quercus prinoides	Dwarf Chestnut Oak	G5		DC:SX
Quercus shumardii	Shumard's Oak	G5		MD:S2/T
Ranunculus flabellaris	Yellow Water-Crowfoot	G5		MD:S1/E
Ruellia humilis	Hairy Wild-Petunia	G5		MD:SU/X
Ruellia strepens	Rustling Wild-Petunia	G4G5		MD:S1/E
Rumex altissimus	Tall Dock	G5		MD:S1/E
Salix exigua	Sandbar Willow	G5		DC:SX
Scutellaria galericulata	Common Skullcap	G5		MD:S1
Scutellaria nervosa	Veined Skullcap	G5		MD:S1/E
Scutellaria parvula	Small Skullcap	G4		DC:SX
Scutellaria saxatilis	Rock Skullcap	G4?		MD:S1/E
Sida hermaphrodita	Virginia Mallow	G2		MD:S1/E
Silene nivea	Snowy Campion	G4?		MD:S1/E
Silphium trifoliatum	Three-Leaved Rosinweed	G4?		DC:S1
Solidago rupestris	Rock Goldenrod	G4?		MD:S1/X
Solidago simplex var racemosa	Riverbank Goldenrod	G5T4?		DC:S1
Solidago spathulata	Riverbank Goldenrod	G5		MD:S1/T
Spermacoce glabra	Buttonweed	G4G5		MD:S1/E
Stachys aspera	Rough Hedge-Nettle	G4		MD:SH/X
Stachys clingmanii	Clingman's Hedge-Nettle	G3		MD:S1/E
Synosma suaveolens	Sweet-Scented Indian-Plantain	G3G4		MD:S1/E
Talinum teretifolium	Fameflower	G4		MD:S1/T
Thalictrum dasycarpum	Purple Meadowrue	G5		DC:S1
Trachelospermum difforme	Climbing Dogbane	G4G5		MD:S1/E
Trichostema setaceum	Narow-Leaved Bluecurls	G5		MD:S1
Trifolium reflexum	Buffalo Clover	G5		DC:SX
Trifolium virginicum	Kate's-Mountain Clover	G3G4	3C	MD:S2S3/T
Triosteum angustifolium	Narrow-Leaved Horse-Gentian	G5		MD:S1/E
Utricularia gibba	Humped Bladderwort	G5		DC:S1
Valeriana pauciflora	Valerian	G4		MD:S1/E
Valeriana chenopodiifolia	Goose-Foot Cornsalad	G5		MD:S1/E
Valeriana umbilicata	Tall Cornsalad	G3G5		MD:SH/X
Veronica scutellata	Marsh Speedwell	G5		DC:SX
Veronicastrum virginicum	Culver's-Root	G5		DC:S1?
Vitis rupestris	Sand Grape	G3?		MD:S1
Zizia aurea	Golden Alexanders	G5		DC:S1S3

EXPLANATION OF GLOBAL, STATE, and FEDERAL SPECIES RANKS for Appendix D

GLOBAL RANK

G1 Highly globally rare.
G2 Globally rare.
G3 Either very rare and local throughout its range or distributed locally (even abundantly at some of its locations) in a restricted range or because of other factors making it vulnerable to extinction throughout its range.
G4 Apparently secure globally, although it may be quite rare in parts of its range, especially at the periphery.
G5 Demonstrably secure globally, although it may be quite rare in parts of its range, especially at the periphery.
G? The species has not yet been ranked.
_Q Species containing a "Q" in the rank indicates that the taxon is of questionable or uncertain taxonomic standing.
_T Ranks containing a "T" indicate that the infraspecific taxon is being ranked differently than the full species.

STATE RANK

S1 Highly State rare. Critically imperiled in Maryland because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation.
S2 State rare. Imperiled in Maryland because of rarity or because of some factor(s) making it vulnerable to becoming extirpated.
S3 Watch List. Rare to uncommon with the number of occurrences. It may have fewer occurrences but with a large number of individuals in some populations, and it may be susceptible to large-scale disturbances.
S3.1 A "Watch List" species that is actively tracked because of the global significance of Maryland occurrences.
S4 Apparently secure in Maryland. It is apparently secure under present conditions, although it may be restricted to only a portion of the State.
S5 Demonstrably secure in Maryland under present conditions.
SA Accidental or a vagrant in Maryland.
SE Established, but not native to Maryland; it may be native elsewhere in North America.
SH Historically known from Maryland, but not verified for an extended period (usually 20 or more years), with the expectation that it may be rediscovered.
SP Potentially occurring in Maryland or likely to have occurred in Maryland (but without persuasive documentation).
SR Reported from Maryland, but without persuasive documentation that would provide a basis for either accepting or rejecting the report (e.g., no voucher specimen exists).
SRF Reported falsely (in error) from Maryland, and the error may persist in the literature.
SU Possibly rare in Maryland, but of uncertain status for reasons including lack of historical records, low search effort, cryptic nature of the species, or concerns that the species may not be native to the State.
SX Believed to be extirpated in Maryland with virtually no chance of rediscovery.
S? The species has not yet been ranked.
S ? A question mark after another rank indicates uncertainty regarding that rank.

STATE STATUS

E Endangered; a species whose continued existence as a viable component of the State's flora or fauna is determined to be in jeopardy.
I In Need of Conservation; an animal species whose population is limited or declining in the State such that it may become threatened in the foreseeable future if current trends or conditions persist.
T Threatened; a species of flora or fauna which appears likely, within the foreseeable future, to become endangered in the State.
X Endangered Extirpated; a species that was once a viable component of the flora or fauna of the State, but for which no naturally occurring populations are known to exist in the State.
* A qualifier denoting the species is listed in a limited geographic area only.

FEDERAL STATUS

LE Taxa listed as endangered; in danger of extinction throughout all or a significant portion of their range.
LT Taxa listed as threatened; likely to become endangered within the foreseeable future throughout all or a significant portion of their range.
PE Taxa proposed to be listed as endangered.
PT Taxa proposed to be listed as threatened.
C Candidate taxa for listing for which the Service has on file enough substantial information on biological vulnerability and threat(s) to support proposals to list them as endangered or threatened.

Appendix E. List of Reviewers

The following individuals provided valuable input during the review process of this report.

Participant	Representing
Kevin Brandt	Assistant Superintendent, Chesapeake & Ohio NHP
Doug Curtis	NPS-National Capital Region
Doug Faris	Superintendent, Chesapeake & Ohio NHP
Mark Flora	NPS-Water Resources Division
Dianne Ingram	Natural Resources Management Specialist, Chesapeake & Ohio NHP
Chuck Pettee	NPS-Water Resources Division
Gary Smillie	NPS-Water Resources Division
Doug Stover	Resources Management Chief, Chesapeake & Ohio NHP
David Vana-Miller	NPS-Water Resources Division
Don Weeks	NPS-Water Resources Division

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-193, August 2001